APPENDIX I

San Francisco Bay Area Environmental Management Plan

Manual of Standards for

SURFACE RUNOFF CONTROL MEASURES

ABAG ASSOCIATION OF BAY AREA GOVERNMENTS

August 1980

MANUAL OF STANDARDS

FOR

SURFACE RUNOFF CONTROL MEASURES

August 1980

Association of Bay Area Governments

September 1980

ERRATA

Manual of Standards for Surface Runoff Control Measures

p. I-35, l. 19	change from "+0.07073 log (X4 + 100)" to "+0.04073 log (X4 + 100)"
p. I-42, l. 5	change from "San Mateo County" to "Alameda County"
p. I-53, l. 18	change from "(e) above)" to "(5) above)"
p. I-55, l. 9	change from "(e) Blando brome" to "Blando brome"
p. I-73, l. 9	change from "See item 6, below" to "See item 6, above"
p. I-82, l. 10	change from "grommets spaced 10 feet" to "grommets spaced no more than 10 feet"
p. I-99, l. 13	change from "V=AD" to "V= 0.4 AD"
p. I-114, l. 4	change from "4 x 10 centimeters per second" to "4 x 10^{-2} centimeters per second"
p. I-127, l. 19	change from "a 10-year-" to "design"
p. I-136, l. 20	change from "32.2 feet per second" to "32.2 feet per second squared"
p. I-142, l. 21	change from "C=" to "X="
p. II-14, Table 11.3.1	replace table with following:

Parameter	Asphalt Surface Accumulation Rate/ Concrete Surface Accumulation Rate
Total solids	2.4
Chromium	2.9
Copper	2.8
Lead	3.0
Cadmium	2.3

These accumulation rate ratios are for equivalent land uses.

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INTRODUCTION

This manual is intended to provide guidance to Bay Area cities and counties in controlling water quality impacts of surface runoff. It suggests a framework for regulation and enforcement and describes technical standards and sample specifications for control measures.

The manual is divided into two sections. Chapter I suggests a program for controlling erosion and sediment from developing areas and focuses on measures to be taken at the construction site. Chapter II recommends local public works practices that would reduce pollution from urban runoff at little or no additional cost.

The program outlined in these chapters is flexible. The various components can be used in their entirety or only in part. They are intended to be revised, amended, incorporated into existing regulations or otherwise adjusted to fit the needs of local jurisdictions in developing their own surface runoff control programs.

The standards and sample specifications for erosion and sediment control measures were adapted from California and nationwide Soil Conservation Service standards and specifications and from Standards and Specifications for Erosion and Sediment Control in Developing Areas (USDA, Soil Conservation Service, Maryland, 1975). Because of the variability of local and site-specific conditions (e.g., rainfall and soil conditions), all standards and sample specifications should be reviewed by a qualified professional before they are adopted by a local jurisdiction.

I. CONSTRUCTION EROSION AND SEDIMENT CONTROL

The denuded slopes of construction sites are a major source of surface runoff pollution in the Bay Area. Particles of nutrient-rich topsoil, displaced by the force of rain and runoff, are carried downslope into stream channels and water bodies below. The resulting water quality problems include sediment buildup and blockage of channels, turbidity, increased algae growth and oxygen depletion.

Principles of Erosion and Sediment Control

The following are principles for controlling erosion and sediment on construction sites:

- fit development to the existing topography, soils and vegetation as much as possible;
- minimize soil exposure during the rainy season by proper timing of grading and construction;
- retain natural vegetation whenever feasible;
- vegetate and mulch denuded areas to protect them from winter rains;
- divert runoff away from steep denuded slopes or other critical areas with barriers or ditches;
- minimize length and steepness of slopes by benching, terracing or constructing diversion structures;
- prepare drainageways to handle concentrated or increased runoff from disturbed areas by using rock riprap, concrete or other lining materials;
- trap sediment-laden runoff in basins to allow soil particles to settle out before flows are released to receiving waters;
- inspect sites frequently to ensure control measures are working properly and correct problems as needed.

Elements of Local Regulatory Programs

Local regulatory programs to implement and enforce such measures should include the following elements:

- an erosion and sediment control ordinance. The ordinance would create a framework for regulation and provide the legal basis for enforcement. It should require applicants for grading permits to submit plans for erosion and sediment control and should define the process for reviewing, approving and enforcing those plans.

Because the ordinance must be applicable to a number of different conditions, it must be a flexible document. It therefore should not contain technical details likely to change over time or that are better determined on a case-by-case basis. These details should instead be included by reference to a handbook or manual of standards and specifications (see below).

- <u>erosion and sediment control plans</u>. As required by the ordinance, a plan should be submitted for each project describing measures for erosion and sediment control on the construction site. The control measures specified must be of an appropriate type and size to accommodate predicted runoff and sediment yield from the site and should be designed according to the standards and specifications prescribed in the handbook (see below).

- <u>a handbook or manual of standards and specifications</u>. The handbook, referenced in the ordinance, should contain standards and specifications for proven, effective procedures for constructing, operating and maintaining control measures. It should be continuously revised to incorporate new data and technological developments, thereby enabling the ordinance to keep pace with technology without legislative revision.

- <u>means of enforcement</u>. The ordinance, with the required erosion and sediment control plans and referenced handbook of standards and specifications, would provide the legal basis for enforcement. Failure to install the required measures or to meet standards would constitute a clear violation of permit requirements. The ordinance would also establish procedures for reporting violations and the fines and penalties that may be imposed.

  The job of the local site inspector would be to see that all requirements of the ordinance are enforced on the site. Guidelines should be established to help him obtain developer compliance and deal with violations.

The following sections of this Chapter present models and descriptions of the elements of an effective regulatory program. They are intended to be used by Bay Area cities and counties in developing their own ordinances, standards and specifications, and enforcement guidelines. It should again be emphasized that these program elements are intended as guides.

A. MODEL EROSION AND SEDIMENT CONTROL ORDINANCE

The Model Erosion and Sediment Control Ordinance, summarized in Table I.A.1, is to be used by local jurisdictions to evaluate the effectiveness of their present grading ordinances in controlling erosion and sediment from construction sites. Where inadequacies are found, the model should then be used to revise or amend the ordinances--or the entire model may be adopted as law.

The model ordinance is limited in scope. It addresses only questions of erosion and sediment control, as it is assumed that other provisions of local ordinances will deal with such questions as slope stability and safety.

In the text of the model, passages or blanks enclosed in brackets are intended to be modified or filled in by local jurisdictions. Substantial changes to other parts of the model should be carefully considered, for such changes may undermine the effectiveness of the regulatory scheme.

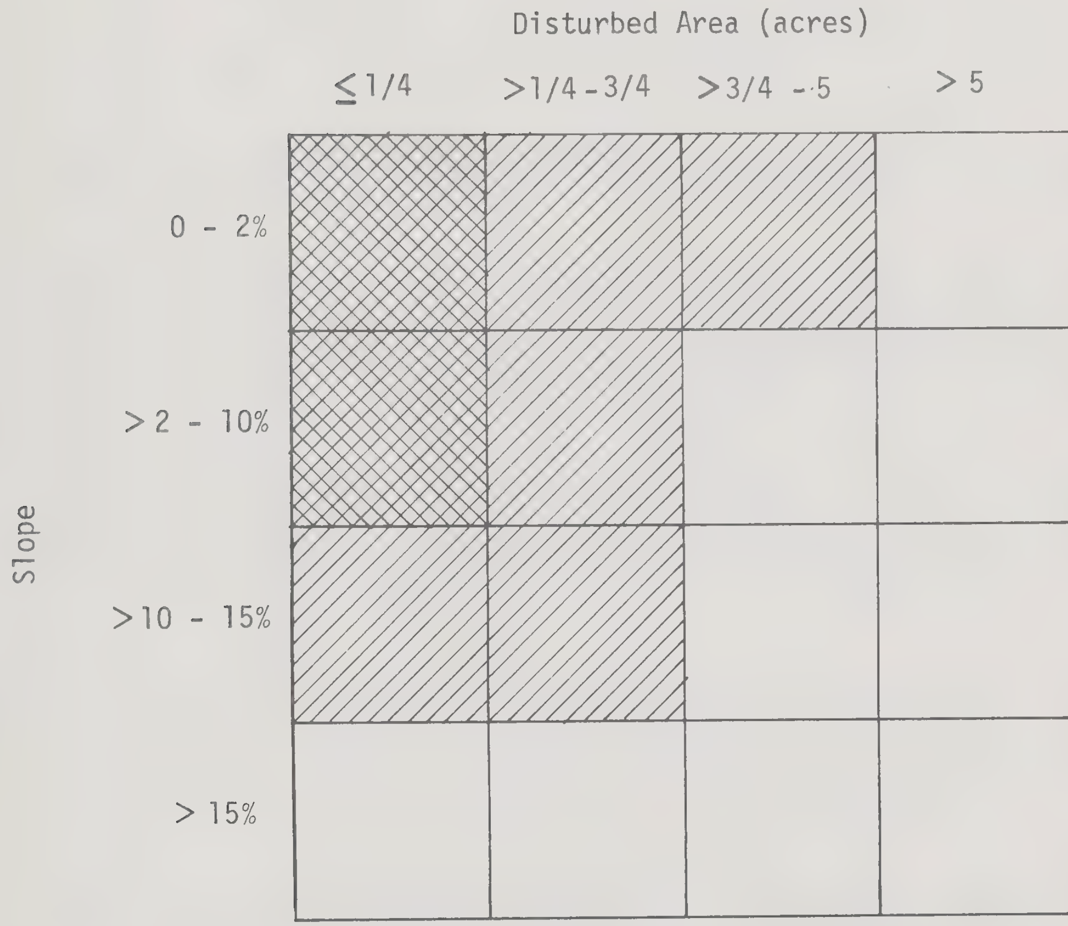
The model is based on analyses of published model ordinances and of existing ordinances in California and other states. It was reviewed by ABAG's Water Quality Technical Advisory Committee and the Citizens Advisory Committee, and revised pursuant to comments from committee members and other interested parties.

The model provides for three levels of regulation. Grading of small, relatively flat sites is exempted from the permit process. Grading of larger sites on flat to moderate slopes is controlled under the Minor permit process. Builders must submit erosion control plans but are not required to report. The site is subject to spot inspections. Grading of large sites or sites on steep slopes is controlled under the Major permit process. In addition to submitting erosion control plans, builders of these projects must report according to a schedule and the site is subject to scheduled inspections. Table I.A.2 summarizes this regulatory scheme.

TABLE I.A.1 OUTLINE OF MODEL EROSION AND SEDIMENT CONTROL ORDINANCE

	Ordinance Features	Section(s)
1.	Water quality is an explicit goal of the ordinance and a key criterion of the review process.	101.01., 301.01
2.	An erosion and sediment control plan is required prior to issuance of a grading permit.	201.02, 202.03, 202.04
3.	A manual of standards for surface runoff control measures on construction sites is maintained by the jurisdiction for use by developers and agency plan reviewers.	301.03, 301.04
4.	A schedule of reports, tied to the rainy season, is required of permittees.	402.01
5.	A schedule of inspections, tied to permittee reports and the rainy season, is required of the agency.	402.02(b)
6.	A variety of enforcement mechanisms, triggered by inspections, reports or other permittee or agency actions, is available to the local agency.	402.01, 403.02, 403.03

TABLE I.A.2 THRESHOLD LEVELS FOR MINOR AND MAJOR PERMITS IN MODEL EROSION CONTROL ORDINANCE



No permit required

Minor permit: erosion control plans, spot inspections

Major permit: erosion control plans, scheduled reports, scheduled inspections

MODEL EROSION AND SEDIMENT CONTROL ORDINANCE

(To Amend an Existing Grading Ordinance)

Article I

Title, Purpose and General Provisions

101.00 Title. This ordinance shall be known as the "[City/County] Erosion and Sediment Control Ordinance" and may be so cited.

101.01 Purpose. The purpose of this Chapter is to promote and protect the public interest by regulating land disturbances, land fill and soil storage in connection with the clearing and grading of land for construction. The intent of this ordinance is to establish administrative procedures, minimum standards of review and implementation and enforcement procedures for the protection and enhancement of the water quality of watercourses, water bodies and wetlands, natural and man-made, by controlling erosion, sedimentation, increases in surface runoff and related environmental damage caused by construction-related activities.

101.02 Definitions. When used in this Chapter, the following words shall have the meanings ascribed to them in this Section:

(a) Administrator: the Director of [ ] and duly authorized agents and employees of [ ].

(b) Applicant: any person, corporation, partnership, association of any type, public agency or any other legal entity who submits an application to the Administrator for a permit pursuant to this Chapter.

(c) Best Management Practice (BMP): a technique or series of techniques which, when utilized in a designated manner, is proven to be effective in controlling construction-related runoff, erosion and sedimentation (see §101.02(i)).

(d) Erosion: the action or process of wearing away of earth or soil by the action of water.

(e) Final Erosion and Sediment Control Plan: a set of measures designed to control surface runoff and erosion and to retain sediment on a particular site after all other planned final structures and permanent improvements have been erected or installed.

(f) Interim Erosion and Sediment Control Plan: a set of measures designed to control surface runoff and erosion and to retain sediment on a particular site during the period in which pre-construction and construction-related land disturbances, fills and soil storage occur.

(g) Land disturbance/land disturbing activities: any human activity moving or removing the soil mantle or top 6 inches of soil whichever is shallower.

(h) Land fill: any human activity depositing soil or other earth materials.

(i) Manual of Standards (Manual): a compilation of technical application standards and design specifications adopted by the Administrator as being proven methods of controlling construction-related surface runoff, erosion and sedimentation (see §101.02(c)).

(j) Permittee: the applicant in whose name a valid permit is duly issued pursuant to this Chapter and his/her/its agents, employees and others acting under his/her/its direction.

(k) Sediment: material deposited by water.

(l) Site: a parcel or parcels of real property owned by one or more than one person which is being or is capable of being developed as a single project.

(m) Wet season: the period from [October 15 to April 15].

(n) Watercourse: [to be defined and designated by the local jurisdiction].

101.03 Severability and Validity. If any part of this ordinance is found not valid, the remainder of this ordinance shall remain in effect.

101.04 Nuisance Abatement. Neither this Chapter, nor any administrative ruling made under it, limits:

(a) The power of the [City/County] to declare, prohibit and abate a nuisance; or

(b) The right of any person to maintain, at any time, any appropriate action for relief against any private nuisance, or for relief against any contamination or pollution.

Article II

Permit Application Procedures

201.01 Scope. No person may grade, fill, excavate, store or dispose of soil and earthen materials or perform any other land-disturbing or land-filling activity without first obtaining a Permit as set forth in this Chapter.

201.02 Exemptions. All land-disturbing or land-filling activities or soil storage shall be undertaken in a manner designed to minimize surface runoff, erosion and sedimentation. A person performing such activities need not apply for a Permit pursuant to this Chapter in the following situations:

(a) Development or construction, on a single lot, of a single family residence when undertaken by the owner, and for which no prior permit pursuant to this Chapter has been issued, provided such activities also meet the requirements of Subsection (b) of this Section;

(b) Land disturbance or land fill of [1/4 acre or less on natural and finished slopes less than 10%]; or, where the volume of earth, soil or other earthern materials stored or disposed of is [50 cu. yds.] or less, or [50 tons] or less;

(c) Routine cemetary excavations and fills;

(d) Routine agricultural crop management practices;

(e) Emergencies posing an immediate danger to life or property, or substantial flood or fire hazards.

Except for Subsection (e) of this Section, the exemptions set forth in this Section shall not apply when the activity is undertaken in the following situations:

(1) on natural and finished slopes greater than 15%, or

(2) within 100 feet by horizontal measurement from the top of the bank of a watercourse, the mean high watermark (line of vegetation) of a body of water or within the wetlands associated with a watercourse or water body, whichever distance is greater.

202.00 Application. The application for a Permit must include all of the following items:

(a) Application form;

(b) Site Map and Grading Plan;

(c) Interim Erosion and Sediment Control Plan;

(d) Final Erosion and Sediment Control Plan, where required (see §301.07);

(e) Soils and Geological Reconnaissance Report, where required (see §301.05);

(f) Work schedule;

(g) Application fees;

(h) Performance bond or other acceptable security (see §202.07);

(i) Any supplementary material required by the Administrator.

202.01 Application Form. The following information is required on the application form:

(a) Name, address and telephone number of the Applicant;

(b) Names, addresses and telephone numbers of any and all contractors, subcontractors or persons actually doing the land-disturbing activity and their respective tasks;

(c) Name(s), address(es) and telephone number(s) of the person(s) responsible for the preparation of the Site Map and Grading Plan;

(d) Name(s), address(es) and telephone number(s) of the person(s) responsible for the preparation of the Interim and/or Final Erosion and Sediment Control Plan;

(e) Name, address and telephone number of the registered [Geologist] responsible for the preparation of the Soils and Geological Reconnaissance Report, where required (see §301.05);

(f) A vicinity map showing the location of the site in relationship to the surrounding area's watercourses, water bodies and other significant geographic features, and roads and other significant structures;

(g) Date of the application;

(h) Signature(s) of the owner(s) of the site or of an authorized representative.

202.02 Site Map and Grading Plan. The Site Map and Grading Plan shall contain all the following information:

(a) Existing and proposed topography of the site taken at not more than a [x-foot] contour interval over the entire site. Ninety percent (90%) of the contours shall be plotted within one contour interval of the true location;

(b) Two contour intervals that extend a minimum of [100 feet off-site, or sufficient to show on- and off-site drainage];

(c) Site's property lines shown in true location with respect to the plan's topographic information;

(d) Location and graphic representation of all existing and proposed natural and man-made drainage facilities;

(e) Location and graphic representation of proposed excavations and fills, of on-site storage of soil and other earthen material, and of on-site disposal;

(f) Location of existing vegetation types and the location and type of vegetation to be left undisturbed;

(g) Location of surface runoff, erosion and sediment control measures as required under §202.03(d);

(h) Quantity of soil or earthen materials in tons and cubic yards to be excavated, filled, stored or otherwise utilized on-site;

(i) Outline of the methods to be used in clearing vegetation, and in storing and disposing of the cleared vegetative matter;

(j) Proposed sequence and schedule of excavation, filling and other land-disturbing and filling activities, and soil or earthen material storage and disposal.

202.03 Interim Erosion and Sediment Control Plan (Interim Plan). All the following information shall be provided with respect to conditions existing on the site during land-disturbing or filling activities or soil storage:

(a) Maximum surface runoff from the site shall be calculated using the method approved by the Administrator and maintained in the Manual, or any other method proven to the Administrator to be as or more accurate;

(b) Sediment yield shall be calculated using the method approved by the Administrator and maintained in the Manual, or any other method proven to the Administrator to be as or more accurate;

(c) The Interim Plan shall also contain the following information:

(1) a delineation and brief description of the measures to be undertaken to retain sediment on the site, including, but not limited to, the designs and specifications for berms and sediment detention basins, and a schedule for their maintenance and upkeep,

(2) a delineation and brief description of the surface runoff and erosion control measures to be implemented, including, but not limited to, types and method of applying mulches, and designs and specifications for diverters, dikes and drains, and a schedule for their maintenance and upkeep,

(3) a delineation and brief description of the vegetative measures to be taken, including, but not limited to, seeding methods, the type, location and extent of pre-existing and undisturbed vegetation types, and a schedule for maintenance and upkeep;

(d) The location of all the measures listed by the Applicant under Subsection (c) above, shall be depicted on the Site Map and Grading Plan (see §202.02 (f)-(g));

(e) An estimate of the cost of implementing and maintaining all interim erosion and sediment control measures must be submitted in a form acceptable to the Administrator.

202.04 Final Erosion and Sediment Control Plan (Final Plan). All the following information shall be provided with respect to conditions existing on the site after final structures and improvements (except those required under this Section) have been completed and where these final structures have not been covered by an Interim Plan, (see §301.07):

(a) Maximum runoff from the site shall be calculated using the method approved by the Administrator and maintained in the Manual, or any other method proven to the Administrator to be as or more accurate;

(b) Sediment yield shall be calculated using the method approved by the Administrator and maintained in the Manual, or any other method proven to the Administrator to be as or more accurate;

(c) The Final Plan shall also contain the following information:

(1) a description of and specifications for sediment retention devices,

(2) a description of and specifications for surface runoff and erosion control devices,

(3) a description of vegetative measures,

(4) a graphic representation of the location of all items in Subsections (1)-(3) above;

(d) An estimate of the costs of implementing all final erosion and sediment control measures must be submitted in a form acceptable to the Administrator.

202.05 Soils and Geological Reconnaissance Report (Soils Report). A Soils Report, when required by the Administrator (see §301.05), shall be based on adequate test borings, as necessary, and shall contain all the following information:

(a) Data regarding the nature, distribution and erodibility of existing soils;

(b) Data regarding the nature, distribution and erodibility of soil to be placed on the site, if any;

(c) Conclusions and recommendations for grading procedures;

(d) Conclusions and recommended designs for interim soil stabilization devices and measures and for permanent soil stabilization after construction is completed.

202.06 Work Schedule. The Applicant must submit a master work schedule showing the following information:

(a) Proposed grading schedule;

(b) Proposed conditions of the site on each [July 15, August 15, September 15, October 1 and October 15] during which the Permit is in effect;

(c) Proposed schedule for installation of all interim erosion and sediment control measures including, but not limited to, the stage of completion of erosion and sediment control devices and vegetative measures on each of the dates set forth in Subsection (b);

(d) Schedule for construction, if any;

(e) Schedule for installation of permanent erosion and sediment control devices where required (see §301.07).

202.07 Security

(a) The Applicant shall provide security for the performance of the work described and delineated on the approved Grading Plan in an amount to be set by the Administrator [but not to exceed 100%] of the approved estimated cost of the grading. The form of security shall be one or a combination of the following to be determined by the Administrator:

(1) bond or bonds issued by one or more duly authorized corporate sureties. The form of the bond or bonds shall be subject to the approval of the [City Attorney/County Counsel],

(2) deposit, either with the city or a responsible escrow agent or trust company at the option of the [City/County], of money, negotiable bonds of the kind approved for securing deposits of public monies, or other instrument of credit from one or more financial institutions subject to regulation by the State or Federal government wherein said financial institution pledges funds are on deposit and guaranteed for payment.

(b) The Applicant shall provide security for the performance of the work described and delineated in the Interim Plan in an amount to be determined by the Administrator but not less than 100% of the approved estimated cost of performing said work. The form of the security shall be as set forth in Subsections (a)(1) and (2).

(c) The Applicant shall provide security for the performance of the work described and delineated in the Final Plan in an amount to be determined by the Administrator but not less than 100% of the approved estimated cost of performing said work. The form of the security shall be as set forth in Subsections (a)(1) and (2).

203.01 Fees. The following fees are to be paid pursuant to a schedule of fees adopted, and amended from time to time by the [City Council/Board of Supervisors] upon recommendation by the Administrator:

(a) A permit processing fee, to be paid at the time the permit application is submitted;

(b) An inspection fee to be paid at the completion of the work described in the Interim Plan;

(c) An inspection fee to be paid at the completion of the work described in the Final Plan;

(d) The Administrator may at his option require partial payment of the fees set forth in Subsections (b) and (c) of this Section before issuing a permit.

204.01 Decision on a Permit. The Administrator shall review all documents submitted pursuant to this Chapter and, if necessary, request additional data, clarification of submitted data or correction of defective submissions within 10 working days after the date of submission. The Administrator shall notify Applicant of his decision on the permit within 20 working days of the initial submission or of the corrected submissions, whichever is later.

204.02 Permit Issuance. Approval of an application by the Administrator shall be issued, if at all, within [3] working days.

204.03 Permit Duration. Permits issued under this Chapter shall be valid for the period during which the proposed land-disturbing or filling activities and soil storage takes place or is scheduled to take place, whichever is shorter. Permittee shall commence permitted activities within 60 days of the scheduled commencement date for grading or the Permitee shall resubmit all required application forms, maps, Plans, schedules and security to the Administrator. The Administrator may require additional fees.

204.04 Permit Denial. The Applicant may request a hearing before the [City Council/Board of Supervisors] within [5] working days of notification of a permit denial. The hearing shall be held within [15] working days.

204.05 Assignment of Permit. A Permit issued pursuant to this Chapter may be assigned, provided:

(a) The Permittee notifies the Administrator of the proposed assignment;

(b) The proposed assignee:

(1) submits an application form pursuant to §202.01, and

(2) agrees in writing to all the conditions and duties imposed by the Permit, and

(3) agrees in writing to assume responsibility for all work performed prior to the assignment, and

(4) provides security pursuant to §202.07, and

(5) agrees to pay all applicable fees pursuant to §202.08;

(c) The Administrator approves the assignment.

The Administrator shall set forth in writing the reasons for his/her approval or disapproval of an assignment.

Article III

Review Standards and Procedures

301.01 Review Policy. The Administrator shall issue a Permit provided he/she finds that the plans submitted in application for a Permit individually and in the aggregate:

(a) Protect the quality of receiving waters;

(b) Minimize surface runoff, erosion and off-site sedimentation:

(1) to the extent feasible, or

(2) in the case where the work site is situated in a §201.02(1)-(2) area, to the extent possible.

301.02 Site Map and Grading Plan. Before approving the Site Map and Grading Plan, the Administrator shall find as required by §301.01.

(a) The review process shall include, but is not limited to, examination of the Site Map and Grading Plan for:

(1) adherence to the requirements set forth in §202.02,

(2) signature(s) by a [Civil Engineer, or other qualified persons],

(3) internal coherence.

(b) Where the Site Map and Grading Plan cannot be approved as submitted, the Administrator may require the Applicant to adopt one or all of the following measures:

(1) reduce the area of land to be disturbed,

(2) restrict land-disturbing or filling activities or soil storage to the dry season (see also §402.01(c)),

(3) revise and resubmit Site Map and Grading Plan.

(c) The Site Map and Grading Plan, if approved, either as submitted or as modified under Subsection (b), is part of the Permit.

301.03 Interim Plan. Before approving the Interim Plan, the Administrator shall find as required by §301.01.

(a) The Applicant may propose the use of any erosion and sediment control techniques in the Interim Plan provided such techniques are proven to be as or more effective than the equivalent BMP contained in the Manual.

(b) The review process shall include, but is not limited to, examination of each proposed technique, individually or in the aggregate, for:

(1) suitability to and effectiveness under the anticipated conditions at the work site both at the onset of and throughout the wet season,

(2) location(s) on the work site,

(3) size(s), carrying or holding capacity(ies) and design(s) for controlling the predicted surface runoff and sediment yield,

(4) allotted time(s) for full installation and implementation,

(5) sequencing, both among themselves and in concert with land-disturbing activities, especially when land-disturbing and filling activities and soil storage will commence either at the onset of or during the wet season,

(6) proposed maintenance method(s) and schedule(s).

(c) The Administrator shall require the Applicant to change the proposed technique or BMP, or any facet thereof, where he/she deems necessary.

(d) The Interim Plan, as approved or as modified under §402.02(a), is a part of the Permit.

301.04 Final Plan. Before approving the Final Plan, the Administrator shall find as required under §301.01.

(a) The Applicant may propose the use of any erosion and sediment control techniques in the Final Plan provided such techniques are proven to be as or more effective than the equivalent BMP contained in the Manual.

(b) The review process shall include, but is not limited to, examination of each proposed technique, individually and in the aggregate, for:

(1) suitability to and effectiveness under the anticipated conditions at the work site throughout the period during which the Final Plan is to be implemented and in effect,

(2) location(s) on the work site,

(3) adequacy of the proposed size(s), carrying and holding capacity(ies) and design(s) for controlling the predicted surface runoff and sediment yield,

(4) allotted time(s) for full installation and implementation,

(5) proposed maintenance method(s) and schedule(s).

(c) The Administrator shall require the Applicant to change the proposed technique or BMP, or any facet thereof, where he/she deems necessary.

(d) The Final Plan, as approved or as modified under §402.02(a), is a part of the Permit.

301.05 Soils Report. A Soils Report meeting the criteria set forth in §202.05 shall be required for all Major Permits. A Soils Report shall also be required for a Minor Permit unless the Administrator determines that all of the following apply:

(a) The soil type for the region in which the work site is situated is recorded in the Manual, an official survey by local state or federal agencies or other widely recognized authority in the field of [ ];

(b) The soil type, as recorded, is sufficiently precise to be utilized in the equations, referenced in §§202.03(b) and 202.04(b);

(c) The soil on the work site is representative of the region surveyed by the literature of Subsection (a);

(d) The site is not in a §201.02(1)-(2) area.

301.06 Work Schedule. The Administator shall review the work schedule for overall coherence. Any modifications to the Site Map and Grading Plan, Interim Plan and Final Plan shall be noted on the work schedule and the schedule modified, as necessary.

301.07 Coordination with Other Permits. Where a person applies to the Administrator for a Permit pursuant to this Chapter and either does not apply for the necessary permits to make improvements on the same site or applies for the permits necessary to make only a portion of the prospective improvements on the same site, the Applicant need not submit a Final Plan for the site or those portions of the site wherein Applicant does not plan to make improvements, and this Section shall apply.

(a) The Interim Plan shall be adequate to control surface runoff and sedimentation from the unimproved areas of the site for the period of time between termination of the Permit and implementation of a Final Plan, pursuant to Subsection (c) of this Section.

(b) The security for the Interim Plan shall be retained until a Final Plan(s) has been implemented. The security may be released on a pro rata basis where a Final Plan or series of Final Plans is/are implemented for a portion or portions of the site.

(c) No [building permit, permit of occupancy, etc.] shall be issued until the Applicant for such a permit has presented to the permitting agency certification from the Administrator that:

(1) a Final Plan has been filed with and approved by the Administrator pursuant to this Chapter,

(2) security for the Final Plan has been posted in accordance with §202.07(c),

(3) Applicant presenting such certification has agreed in writing to implement the Final Plan pursuant to the requirements and enforcement procedures of this Chapter,

(4) Applicant has paid all pertinent fees.

Article IV

Implementation and Enforcement

401.01 Minor Permit.

(a) The Administrator shall issue a Minor Permit only if:

(1) total area of disturbed or filled land is [1/4] acre or less, and the natural and finished slopes are greater than 10%, and 15%, or less, or

(2) total area of disturbed or filled land is [3/4] acre or less and greater than [1/4], and the natural and finished slopes are 15%, or less, or

(3) total area of disturbed or filled land is greater than [3/4] acre but less than [5] acres, and the natural and finished slopes are 2%, or less,

Provided, in all of the situations defined in (a)(1)-(3), above:

(4) total volume of stored soil is [1,200 cubic yards] or less, and

(5) none of the activity is in a §201.02(1)-(2) area.

(b) The Minor Permit is issued subject only to the conditions set forth in §401.03.

(c) The Administrator shall enforce a Minor Permit only through the procedures set forth in §403.01, or by inspections at the discretion of the Administrator, or by any other means available at law or in equity.

401.02 Major Permit.

(a) All permits other than Minor Permits issued under this Chapter are Major Permits.

(b) The Major Permit is issued subject to the conditions set forth in §§401.03 and 402.01-02.

(c) The Administrator shall enforce a Major Permit through any procedures set forth in this Article or by any other means available at law or in equity.

401.03 Issuance of Major and Minor Permits. Administrator shall issue a Major or Minor Permit upon approval of a Site Map and Grading Plan, Interim Plan, Final Plan, where required (see §301.07), Soil Report, where required (see §301.05), deposit of appropriate security and payment of fees. The Major and Minor Permits shall be issued subject to the following conditions:

(a) The Permittee shall maintain a copy of the Permit, approved plans and, for Major Permits only, reports required under §402.01, on the work site and available for public inspection during all working hours;

(b) The Permittee shall, at all times, be in conformity with approved Site Map and Grading Plan, Interim and Final Plans.

402.01 Implementation of Major Permits--Permittee's Duties. In addition to performing as required under §401.03, Permittee shall:

(a) Notify the Administrator, at least forty-eight (48) hours beforehand, of the beginning of land-disturbing or filling activities or soil storage;

(b) Submit to the Administrator, reports on:

(1) the progress of or delays in land-disturbing or filling activities or soil storage,

(2) any other departures from the approved Site Map and Grading Plan which may affect implementation of the Interim or Final Plans as scheduled,

(3) possible delays in obtaining materials, machinery, services or manpower necessary to the implementation of the Interim or Final Plans as scheduled,

(4) the progress of or delays in the implementation of the Interim or Final Plans,

(5) any other departures from implementation of the Interim or Final Plans,

(6) according to the schedule set forth below:

(i) for the period from [April 15] to July 31, monthly;

(ii) for the period from August 1 to September 30, weekly;

(iii) for the period from October 1 to October 15, twice a week;

(iv) for the period from [October 16 to April 14], weekly;

(c) When Permittee proposes to commence land-disturbing or filling activities or soil storage during the wet season, Permittee shall demonstrate that land disturbance is relatively minor and that erosion can be easily controlled, or is a necessary and integral part of an Interim Plan for previously-initiated project phases. Where such activities are approved, Permittee shall submit:

(1) a report seventy-two (72) hours prior to and, again, at the start of land-disturbing or filling activities or soil storage,

(2) a report seventy-two (72) hours prior to and, again, at the start of implementing the Interim Plan,

(3) a report upon completion of the Interim Plan,

(4) any other reports required under subsection (b) of this Section.

Each report shall contain, where pertinent, the elements described in Subsections (b)(1)-(5) of this Section;

(d) Submit to the Administrator, upon termination of the Permit:

(1) a report on and graphic representation of the Final Plan, as implemented, and

(2) a copy of the instructions to be given to the new owners of the improved property by the Permittee or his/her agent regarding the maintenance of the surface runoff, erosion and sediment control measures and devices implemented under the Final Plan,

or,

(3) for those areas where no Final Plan is required, a report and graphic representation of the Interim Plan, as implemented, and

(4) contracts for the maintenance and upkeep of the surface runoff, erosion and sediment control measures and devices implemented under the Interim Plan, for the period during which the site will remain unimproved;

(e) Have an authorized representative of each contractor or subcontractor actually performing the land-disturbing or filling activities or soil storage, or actually procuring the materials, machinery, services or manpower for the implementation of Interim or Final Plans, sign each report pertinent to him or her, and certify the contents thereof as true. The Permittee shall sign all reports submitted to the Administrator and shall attest that each is true and accurate to the best of his or her knowledge.

402.02 Implementation of Major Permits--Administrator's Duties.

(a) The Administrator shall review all reports submitted by Permittee. Where the Administrator finds:

(1) delays in implementing or departures from the approved Site Map and Grading Plan, Interim or Final Plans,

(2) problems with or breakdowns in any technique provided for by the Interim or Final Plan which are attributable to:

(i) the Plans themselves,

(ii) their maintenance methods or schedules,

(iii) any other causes,

which may have a deleterious effect on the quality of receiving waters, or increase surface runoff, erosion or off-site sedimentation, the Administrator shall require the Site Map and Grading Plan, Interim or Final Plans, and maintenance methods and schedules be modified so as to achieve the same level of water quality and surface runoff, erosion and sediment control as would have been achieved had these problems not arisen. The Administrator shall notify the Permittee in writing of the requirement. Permittee shall comply with the order to modify within [x] working days.

(b) The Administrator shall inspect the work site for compliance with conditions set forth in §401.03, for verification of reports submitted under §402.01, and for the quality of the work being performed under the Interim or Final Plan. Said inspections shall take place:

(1) [within five (5) working days of July 15],

(2) [within five (5) working days of September 1],

(3) [within five (5) working days of September 15],

(4) [weekly from October 1 through 15],

(5) [within three (3) working days of] or during, the first major rainfall of the wet season,

(6) under circumstances described in §402.01(c),

(i) at the onset of implementation of the Interim Plan, and

(ii) at the onset of land-disturbing or filling activities or soil storage,

(7) after notification to the Permittee of an order to modify under Subsection(a) of this Section,

(8) at any other time, at the Administrator's discretion.

(c) The inspector shall file a written memorandum on:

(1) the conditions of the work site,

(2) whether Permittee is in compliance with approved plans,

(3) whether Permittee is in conformity with filed reports,

(4) whether Permittee is in comformity with the Interim or Final Plan,

(5) whether Permittee is effectively controlling surface runoff, erosion and off-site sedimentation.

403.01 <u>Suspension or Revocation of Permit</u>. The Administrator shall first have resort to the procedures set forth in this Section before any other enforcement procedure set forth in this Article.

(a) The Administrator shall suspend the Permit and issue a stop work order, and Permittee shall cease all work on the work site, except work necessary to remedy the cause of the suspension, upon notification of such suspension when:

(1) Permittee fails to submit reports timely and in accordance with §402.01,

(2) inspection by the Administrator under §402.02(b)(1)-(8) reveals that the work or the work site:

(i) is not in compliance with the conditions set forth in §401.03, or

(ii) is not in conformity with the Site Map and Grading Plan, Interim or Final Plan as approved or as modified under §402.02(a), or

(iii) is at variance with reports submitted under §402.01(a)-(e), or

(iv) is not in compliance with an order to modify under §402.02(a),

(3) Permittee fails to comply with an order to modify within the time limits imposed by the Administrator (see §402.02(a)).

(b) The Administrator shall revoke the Permit and issue a stop work order, and Permittee shall cease work upon the occurrence of any of the following conditions:

(1) Permittee fails or refuses to cease work, as required under (a) above, after suspension of the Permit and receipt of a stop work order and notification thereof,

(2) any of the conditions set forth in Subsection (a) of this Section occurs in a §201.02(1)-(2) area.

(c) The Administrator shall reinstate a suspended Permit upon Permittee's correction of the cause of the suspension.

(d) The Administrator shall not reinstate a revoked Permit.

403.02 Fines and Penalties. It shall be a misdemeanor for any person to perform work in violation of a stop work order issued pursuant to §403.01(a)-(b). The [City/County] may impose a fine of $500 and/or a prison term of thirty (30) days for each day that:

(a) Permittee continues working in violation of a stop work order;

(b) Permittee is not in compliance with the Interim Plan or Final Plan at the onset of the wet season.

403.03 Action against/Release of the Security. The Administrator may request the [City Attorney/District Attorney] to commence an action against the pertinent security if:

(a) The Permittee ceases land-disturbing activities and abandons the work site prior to completion of the Site Map and Grading Plan;

(b) The Permittee fails to conform to the Interim Plan as approved or as modified under §402.02(a);

(c) The Permittee fails to comply with the Final Plan or an Interim Plan as approved or modified under §402.02(a); or the techniques utilized under either Plan fail within one (1) year of installation, or a Final Plan is implemented for the site or portions of the site, whichever is later;

The monies obtained from a successful action against the Security shall be used to finance remedial work undertaken by the [City/County] or a private contractor under contract to the [City/County], and to reimburse the [City/County] for the cost of litigation;

(e) Securities held against the successful completion of the Site Map and Grading Plan and the Interim Plan, except for Interim Plans described in §301.07, shall be released to the Permittee at the termination of the Permit, provided no action against such security is filed prior to that date;

(f) Securities held against the successful completion of the Final Plan and an Interim Plan described in §301.07 shall be released to the Permittee either one (1) year after termination of the Permit or when a Final Plan is submitted for the unimproved site, whichever is later, provided no action against such security has been filed prior to that date.

403.04 Cumulative Enforcement Procedures. The procedures for enforcement of a Permit, as set forth in this Article, are cumulative and not exclusive.

B. EROSION AND SEDIMENT CONTROL PLANS

An effective erosion and sediment control ordinance should require an erosion control plan (ECP). This plan should be submitted as part of a grading permit application. The ordinance should specify two levels of regulation. For small developments on relatively flat land, simple, non-engineered ECP's may be submitted. For large or hillside developments, engineered ECP's should be required.

The guidelines for erosion and sediment control plans on the following pages are intended to be adopted by local planning and public works departments. They may be added to existing procedures manuals or incorporated into internal guidance memoranda for staff.

Following the guidelines is a sample erosion and sediment control plan that demonstrates how the guidelines may be applied to conditions of a particular project.

EROSION AND SEDIMENT CONTROL PLAN GUIDELINES

Definition

An Erosion and Sediment Control Plan is a document that specifies how erosion and sediment will be controlled on a construction site in compliance with laws, ordinances, and accepted standards and specifications.

Plan Preparer

The plan shall be prepared and signed by a person or firm qualified by training and experience to have expert knowledge of erosion and sediment control methods.

Content

The plan shall consist of three parts:

1. A narrative, containing:

   - a brief description of the overall project;

   - the date grading will begin and the expected date of stabilization;

   - phasing of land-disturbing activities, including removal and stockpiling of topsoil;

   - a brief description of erosion and sediment control measures to be implemented, including both temporary and permanent measures;

     (Note: Measures must meet or exceed all requirements in the Erosion and Sediment Control Ordinance and applicable standards and specifications. If grading is scheduled to be completed before the rainy season begins, the plan should specify contingency actions to winterize the site if construction should fall behind schedule.)

   - a maintenance program, with provisions for frequency of inspection, reseeding of vegetated areas, repair or reconstruction of damaged structures, cleanout method and frequency, disposal of waste materials and disposition of control measures after they have served their purpose (see Sample Erosion and Sediment Control Plan).

(This narrative is intended to summarize for the plan checker the aspects of a project important for erosion control. It is not intended to duplicate the requirements of project applications and EIRs. Applicable portions of those documents should be referenced in the narrative.)

2. A map showing:

   - o existing topography and site conditions;
   - o location of the project relative to highways, municipalities, major streams or other identifiable landmarks;
   - o acreage of the project;
   - o contours at an interval and scale sufficient for distinguishing runoff patterns prior to and after disturbance;
   - o limits of clearing and grading;
   - o critical environmental areas within or near the project areas, such as streams, lakes, ponds and wetland areas;
   - o nature and extent of existing vegetation;
   - o surface area of each soil type and relative erodibility;
   - o location and types of both temporary and permanent control measures;
   - o dimensional details of facilities (see Figure I.B.1).

3. Construction drawings or sketches and supporting data, including:

   - o key dimensions and other important details;
   - o engineering and design assumptions and calculations (for structural measures);
   - o a brief analysis of problems posed by storm runoff on downstream areas.

SAMPLE EROSION AND SEDIMENT CONTROL PLAN

Description

The project is a 4,000-square-foot school building with exercise fields on a 6-acre site.

Grading and Erosion Control Schedule

Grading project is scheduled to start on June 15, 1980. Temporary erosion control measures to be fully implemented by October 1, 1980. Permanent control measures to be installed by August 31, 1981.

Sequence of Land-Disturbing Activities

In June and July 1980, the school site and surrounding area will be stripped and the topsoil stockpiled at the southeast corner of the site. This area will then be brought to grade without disturbance to other areas. Construction of sediment basins and diversion dikes will commence thereafter and be completed before October 15, 1980. All areas brought to grade, except the building site, will be seeded with temporary vegetation and mulched by September 15, 1980.

Soil Data

The entire site is Glenelg silt loam, eroded rolling phase; this soil ranges from moderately to severely erodible.

Erosion Control Program

Seed and straw mulch are to be applied to all graded areas, except for building areas, a 30-foot border, streets and parking areas, not later than September 15, 1980. The straw will be anchored by punching with a roller.

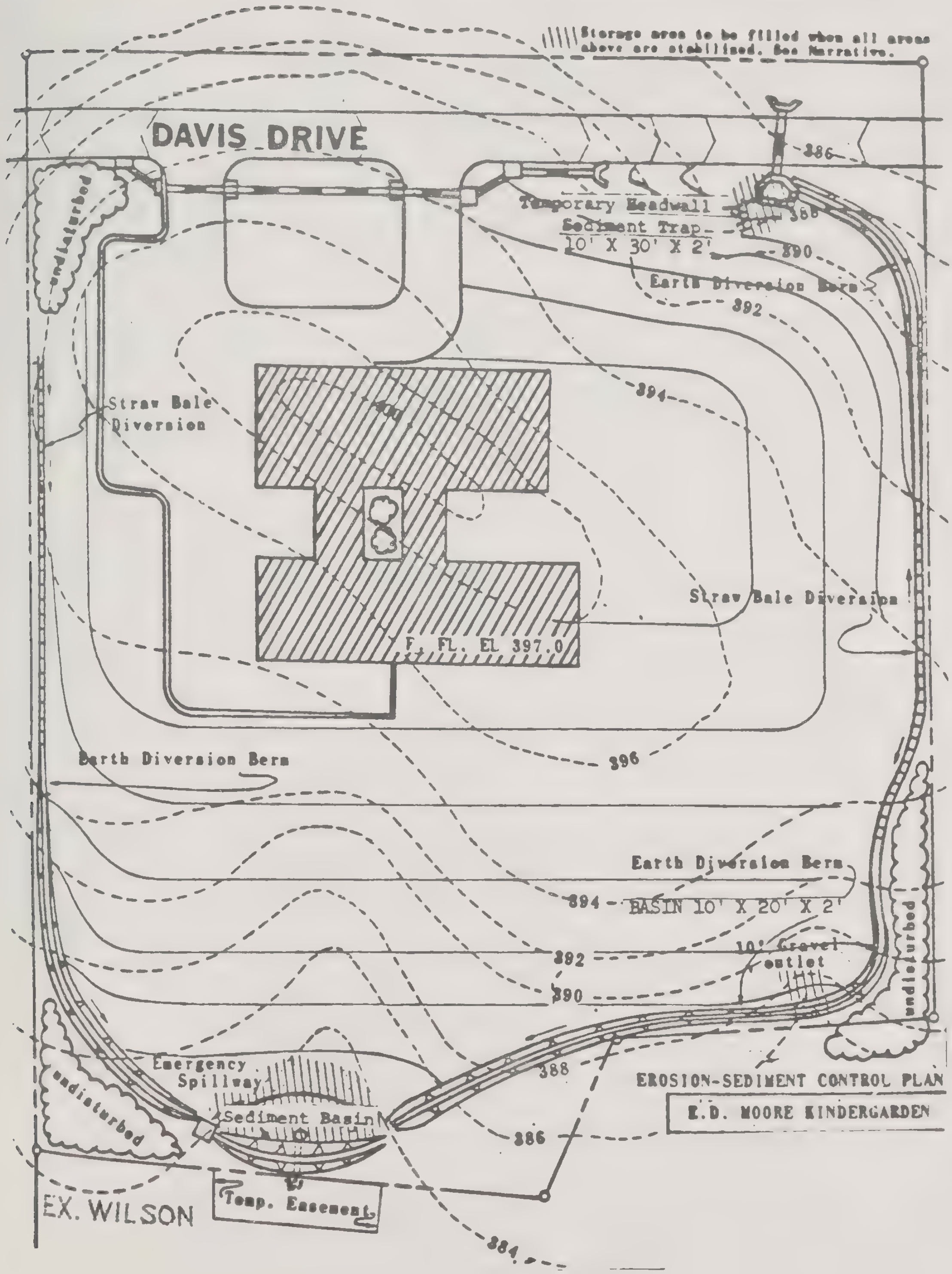
Sediment Control Program

Control will be exercised through installation of 1 earth sediment dam of 0.5 acre-foot capacity and a minor sediment basin of 0.15 acre-foot capacity, with 1,500 feet of earth diversions directing storm runoff to the basins.

Maintenance Program

All measures are to be inspected daily by the site superintendent or his representative. Any damaged structural measures will be repaired by the close of the day. Sediment basins are to be cleaned out at 50% trap efficiency level and the material disposed of by spreading on the site. Diversions may be removed after areas above them have been stabilized with grass or mulch. The sediment basin at the south end will not be removed until all other mechanical measures have been removed and the areas stabilized. No controls are to be removed without approval of the site inspector.

FIGURE I.B.1 EXAMPLE MAP FROM EROSION AND SEDIMENT CONTROL PLAN



(Adapted from Public Facilities Manual, Volume 3, Fairfax County, Virginia, 1978)

Sources and References

1. Amimoto, Perry Y. Erosion and Sediment Control Handbook. California Department of Conservation. May 1978.

2. Fairfax County, Virginia. Public Facilities Manual, Volume 3. 1978.

3. U.S. Department of Agriculture, Soil Conservation Service. Guidelines for Erosion and Sediment Control in California. January 1975.

C. CALCULATING SOIL LOSS AND SURFACE RUNOFF

The Erosion and Sediment Control Ordinance should require predictions of surface runoff and sediment yield as part of all erosion and sediment control plans (see Model Erosion and Sediment Control Ordinance, Sections 202.03(a) and (b) and 202.04(a) and (b)). The results of these calculations should be used by developers in determining the type, size and design of control structures and by the local public works departments in evaluating the appropriateness of the measures to be used (see Model Erosion and Sediment Control Ordinance, Sections 301.01(b)(3) and 301.04(b)(3)).

The techniques described are standard techniques in current use. Developers may choose to use other computational techniques which have been demonstrated to model accurately sediment yield and surface runoff (see Model Erosion and Sediment Control Ordinance, Sections 202.03(a) and (n) and 202.04(a) and (b)).

SOIL LOSS

Five alternative methods of predicting soil loss are described below. The selection of which to use would depend on the accuracy desired, the time available, the precision with which the inputs are known and the expertise of available personnel.

These techniques can predict only the amount of soil moved from its original position; they cannot predict net soil erosion or sediment yield of a river basin.

The first three methods can be used to calculate sheet erosion occurring more or less uniformly over a land surface. To this amount must be added erosion from any roadway cut-and-fill which may be computed according to one of the last two methods in this Section. (Gully erosion, which may also occur, is dealt with in USDA Soil Conservation Service, 1966 and 1975).

The five methods discussed here do not exhaust the list of techniques in current use. They are presented merely to illustrate the factors generally considered in determining sediment yield. The reader is referred to the source documents and other bibliographical entries for more complete discussions before attempting to calculate soil loss.

<u>Pacific Southwest Interagency Committee Method</u>

This method (Pacific Southwest Interagency Committee, 1968) is qualitative and should not be used when precise numerical predictions are required. The sediment yield is estimated as acre-feet per square mile per year. Table I.C.1, with the accompanying example, presents this method.

TABLE I.C.1. PACIFIC SOUTHWEST INTERAGENCY COMMITTEE METHOD FOR ESTIMATING SOIL LOSS

Sediment Yield Levels	A SURFACE GEOLOGY	B SOILS	C CLIMATE	D RUNOFF	E TOPOGRAPHY	F GROUND COVER	G LAND USE	H UPLAND EROSION	I CHANNEL EROSION & SEDIMENT TRANSPORT
High	(10)* a. Marine shales and related mudstones and siltstones.	(10) a. Fine textured; easily dispersed; saline-alkaline; high shrink-swell characteristics. b. Single grain silts and fine sands	(10) a. Storms of several days' duration with short periods of intense rainfall. b. Frequent intense convective storms c. Freeze-thaw occurrence	(10) a. High peak flows per unit area b. Large volume of flow per unit area	(20) a. Steep upland slopes (in excess of 30%) High relief; little or no floodplain development	(10) Ground cover does not exceed 20% a. Vegetation sparse; little or no litter b. No rock in surface soil	(10) a. More than 50% cultivated b. Almost all of area intensively grazed c. All of area recently burned	(25) a. More than 50% of the area characterized by rill and gully or landslide erosion	(25) a. Eroding banks continuously or at frequent intervals with large depths and long flow duration b. Active headcuts and degradation in tributary channels
**									
Moderate	(5) a. Rocks of medium hardness b. Moderately weathered c. Moderately fractured	(5) a. Medium textured soil b. Occasional rock fragments c Caliche layers	(5) a. Storms of moderate duration and intensity b. Infrequent convective storms	(5) a. Moderate peak flows b. Moderate volume of flow per unit area	(10) a. Moderate upland slopes (less than 20%) b. Moderate fan or floodplain development	(0) Cover not exceeding 40% a. Noticeable litter b. If trees present understory not well developed	(0) a. Less than 25% cultivated b. 50% or less recently logged c. Less than 50% intensively grazed d. Ordinary road and other construction	(10) a. About 25% of the area characterized by rill and gully or landslide erosion b. Wind erosion with deposition in stream channels	(10) a. Moderate flow depths, medium flow duration with occasionally eroding banks or bed
**									
Low	(0) a. Massive, hard formations	(0) a. High percentage of rock fragments b. Aggregated clays c. High in organic matter	(0) a. Humid climate with rainfall of low intensity b. Precipitation in form of snow c. Arid climate, low intensity storms d. Arid climate; rare convective storms	(0) a. Low peak flows per unit area b. Low volume of runoff per unit area c. Rare runoff events	(0) a. Gentle upland slopes (less than 5%) b. Extensive alluvial plains	(-10) a. Area completely protected by vegetation, rock fragments, litter Little opportunity for rainfall to reach erodible material	(-10) a. No cultivation b. No recent logging c. Low intensity grazing	(0) a. No apparent signs of erosion	(0) a. Wide shallow channels with flat gradients, short flow duration b. Channels in massive rock, large boulders or well vegetated c. Artificially controlled channels

* THE NUMBERS IN SPECIFIC BOXES INDICATE VALUES TO BE ASSIGNED APPROPRIATE CHARACTERISTICS.
THE SMALL LETTERS a, b, c, REFER TO INDEPENDENT CHARACTERISTICS TO WHICH FULL VALUE MAY BE ASSIGNED.

** IF EXPERIENCE SO INDICATES, INTERPOLATION BETWEEN THE 3 SEDIMENT YIELD LEVELS MAY BE MADE.

In most instances high values for the A through G factors should correspond to high values for the H and/or I factors.

Rating Table

Rating	Sediment Yield AF/sq.mi.
>100	3.0
75 - 100	1.0 - 3.0
50 - 75	0.5 - 1.0
25 - 50	0.2 - 0.5
0 - 25	<0.2

AN EXAMPLE OF THE USE OF THE RATING CHART IS AS FOLLOWS:

A watershed of 15 square miles in western Colorado has the following characteristics and sediment yield levels:

	Factors	Sediment Yield Level	Rating
A	Surface geology	Marine shales	10
B	Soils	Easily dispersed, high shrink-swell characteristics	10
C	Climate	Infrequent convective storms, freeze-thaw occurrence	7
D	Runoff	High peak flows; low volumes	5
E	Topography	Moderate slopes	10
F	Ground cover	Sparse, little or no litter	10
G	Land use	Intensively grazed	10
H	Upland erosion	More than 50% rill and gully erosion	25
I	Channel erosion	Occasionally eroding banks and bed but short flow duration	5
		Total	92

This total rating of 92 would indicate that the sediment yield is between 1.0 and 3.0 AF/sq.mi. based on Rating Table.

Sediment Predictive Yield: Flaxman Method

This method (Flaxman, 1972) computes sediment yield on an average annual rate in acre-feet per square mile per year. The required inputs are:

- precipitation/temperature ratio (X1): average annual precipitation (inches) divided by average annual temperature (degrees F) (use X1 = 0 where vegetation has been stripped for development);
- slope (X2): weighted average slope, such as the contour interval divided by the average width between contours;
- soil particle size (X3): percent of soil particles coarser than 1 millimeter in the uppermost 2 inches of soil;
- aggregation index (X4): percent of soil 2 microns or finer in size in uppermost 2 inches of soil (use (+) if pH is alkaline and (-) if pH is acid or neutral (7.0)).

The equation used to compute sediment yield by this method is:

$$\begin{aligned}\log (Y + 100) = {} & 6.63792 - 2.13712 \log (X1 + 100) \\ & + 0.06284 \log (X2 + 100) \\ & - 0.01616 \log (X3 + 100) \\ & + 0.07073 \log (X4 + 100)\end{aligned}$$

The result of the computation is sediment yield (Y) in acre-feet per square mile per year.

Universal Soil Loss Equation Method

This method of computing sediment yield is in wide use. The calculation is easy once appropriate values of the input variables are obtained. The required inputs are:

- rainfall factor (R): intensity of rainfall (the mechanism responsible for the detachment of soil particles);
- soil erodibility factor (K): susceptibility of soil particles to detachment and transport by rainfall and runoff;
- slope length-gradient factor (SL): combined effect of the geometric features of the site relative to the standard geometry of a basic 9% slope, 72.6 feet long;
- cropping-management factor (C): protection against erosion provided by vegetation;
- erosion-control practice factor (P): ratio of soil loss with the supporting practice to the soil loss with up-and-down hill culture.

The equation used to compute sediment yield by this method is:

$$A = RKSLCP$$

The result of the computation is sediment yield (A) in tons per acre per year.

Road Density vs. Sediment Production Method

This method (as mentioned in Amimoto, 1978), which can be used in the San Francisco Bay Area, can only give a qualitative estimate of the sediment yield due to roadways. This method should be used only in areas of steep topography, moderately erodible soil and moderate rainfall. The graph on Figure I.C.1 is used to estimate sediment yield by this method. Results are in acre-feet per square mile per year.

Surface Area of Cut-and-Fill Method

This method (as mentioned in Amimoto, 1978) can also be used to compute sediment yield due to roadways. The graphically determined area of cut-and-fill is multiplied by the assumed average depth of erosion on the cut-and-fill area. Figures I.C.2 through I.C.4 can be used to determine the cut-and-fill area for 20-, 60- or 100-foot-wide roadways. The result of the computation is sediment yield in acre-feet per road mile per year.

SURFACE RUNOFF

There are several methods for predicting surface runoff.

Stormwater runoff can be estimated using the method described by Victor Mockus (USDA, Soil Conservation Service, 1972) or one of its variations. Briefly, these methods involve determining: (1) a curve number based upon a given set of watershed characteristics, such as surface storage, interception and infiltration of rainwater; (2) the rainfall time distribution; and (3) the drainage area. These methods are particularly useful when quick, on-the-spot estimates of stormwater runoff are needed.

Runoff from areas of 2,000 acres or less with average slopes of less than 30% may be computed using the modification given by the USDA Soil Conservation Service (1973). For areas exceeding these limits or when the computed peak discharge exceeds 2,000 cfs, the runoff may be computed using the Mockus method.

Another common method of predicting runoff is the rational method (as mentioned in Dunne and Leopold, 1978). This method is generally applicable to basins of 200 acres or less, but is often used for areas as large as one square mile (640 acres). It is assumed that a uniform rainfall intensity covers the entire area. The required inputs are:

FIGURE I.C.1

RELATIONSHIP BETWEEN ROAD DENSITY AND SEDIMENT PRODUCTION

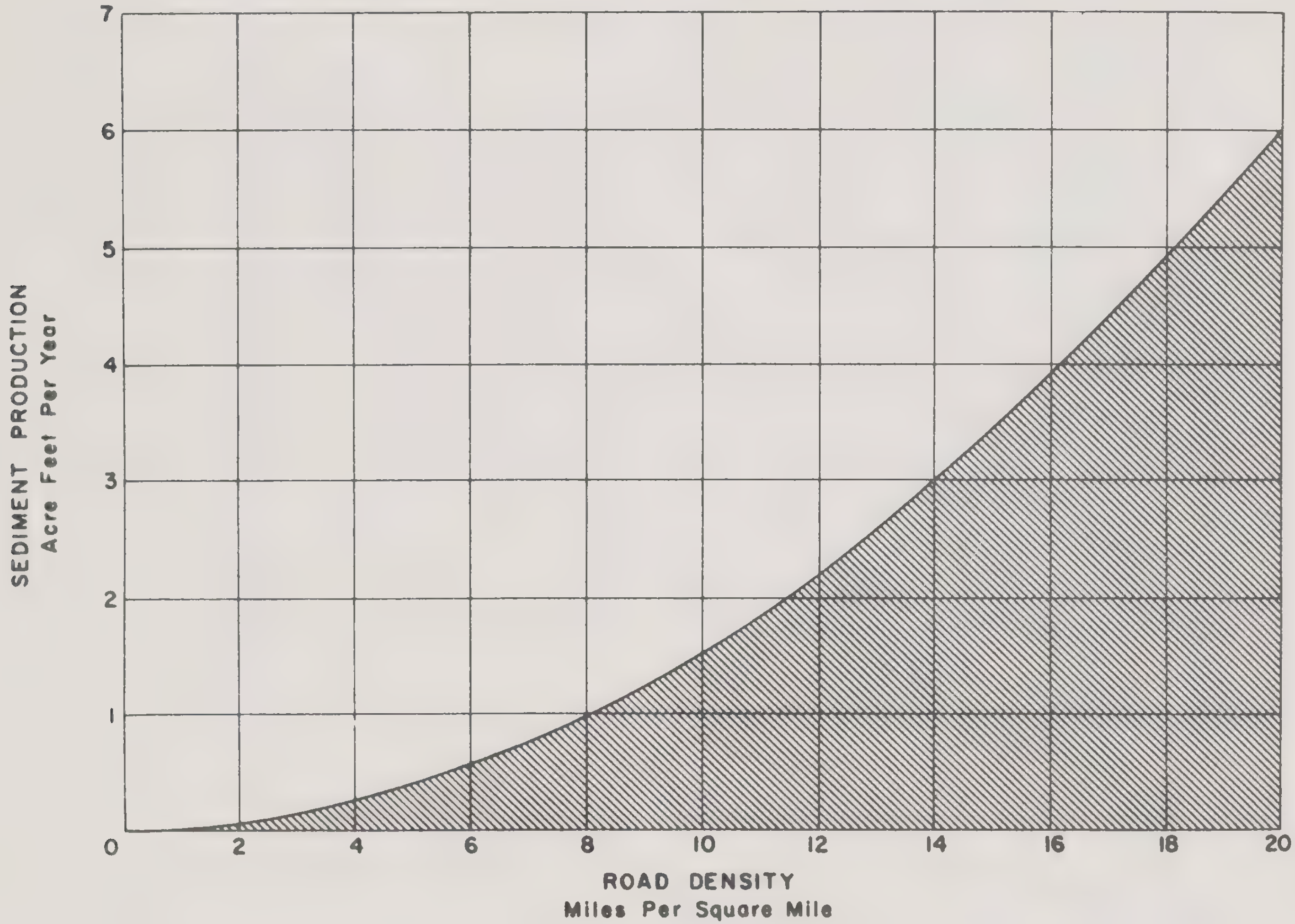


FIGURE I.C.2. CUT AND FILL AREA FOR ROADWAYS--20 FEET WIDE

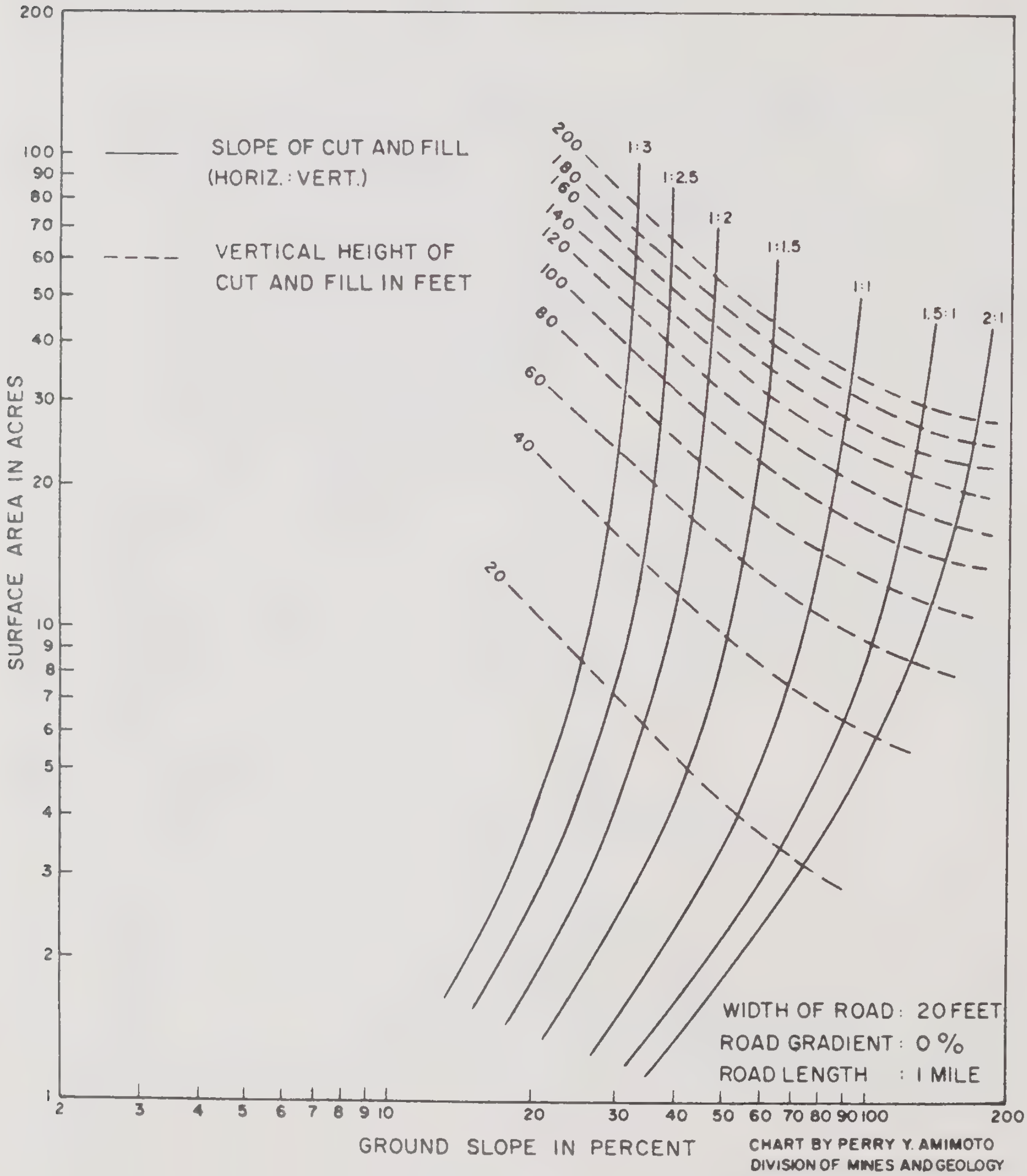


FIGURE I.C.3. CUT AND FILL AREA FOR ROADWAYS--60 FEET WIDE

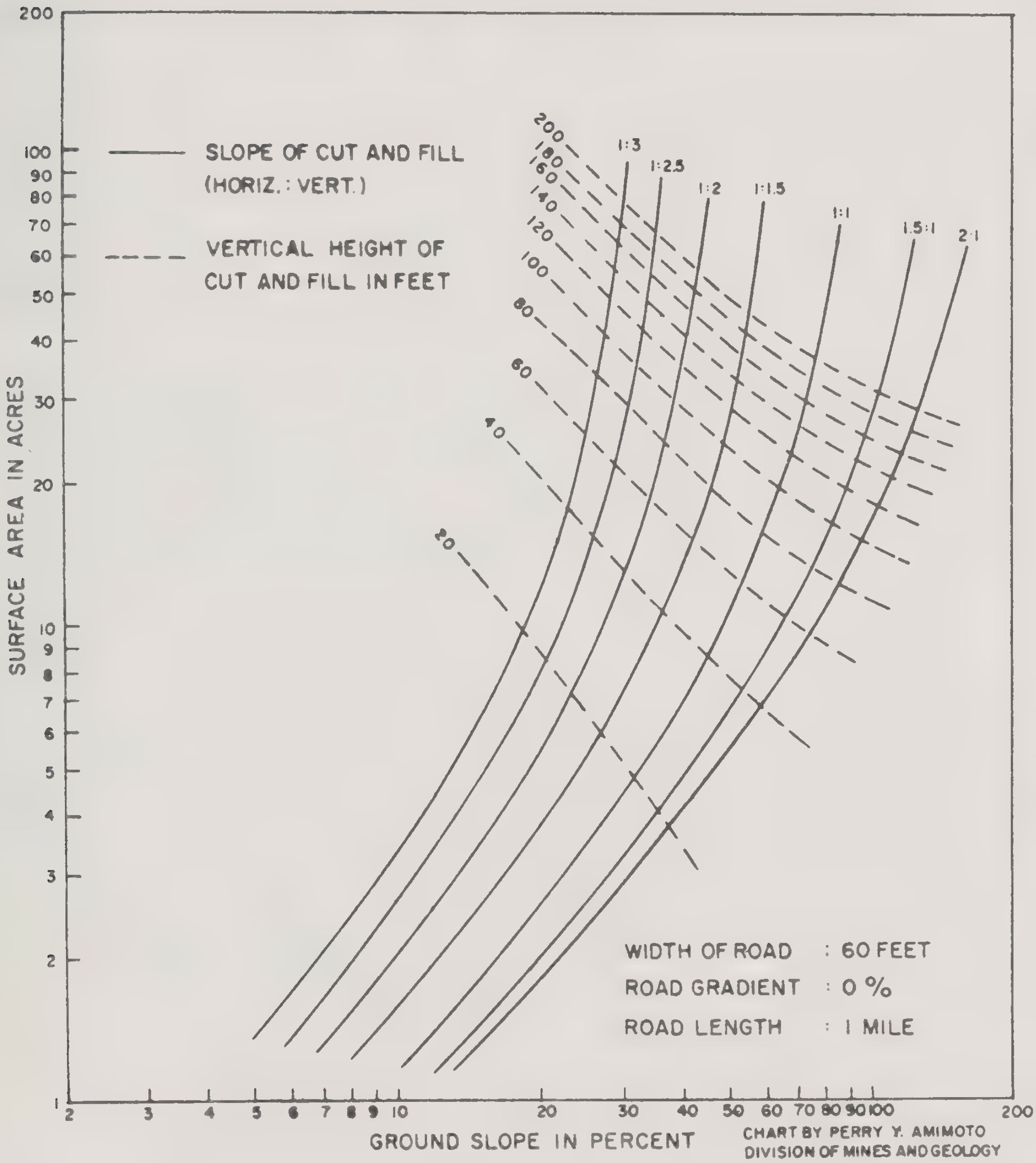


FIGURE I.C.4. CUT AND FILL AREA FOR ROADWAYS--100 FEET WIDE

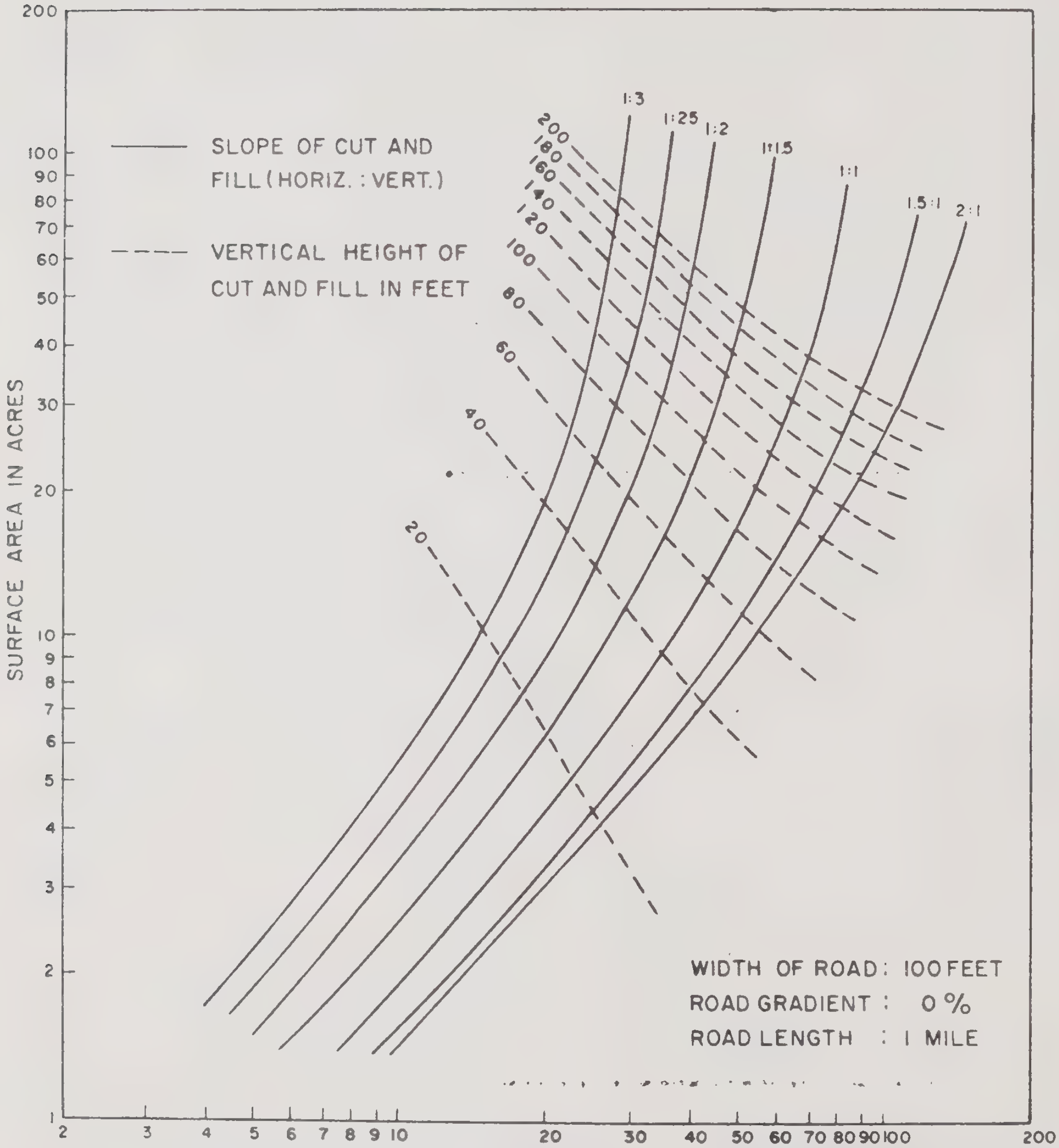


CHART BY PERRY Y. AMIMOTO
DIVISION OF MINES AND GEOLOGY

- rational runoff coefficient (C): a constant that takes into account such basin features as soil type, topography, surface roughness, vegetation and land use (these are assumed not to vary during or between storms);

- rainfall intensity (I): in inches per hour;

- drainage area (A): in acres.

The equation used to compute runoff by this method is:

$$Q = CIA$$

The result of the computation is runoff (Q) in cubic feet per second.

At the beginning of a storm, runoff from distant parts of the basin will not have reached the discharge point where the basin's runoff (Q) is monitored. After a period determined to be typical of each basin, a steady-state flow or peak Q will occur. This is the Q predicted by the rational method. The initial period, known as the time of concentration, may be estimated using techniques described by the USDA Soil Conservation Service (1972).

Selection of Design Storm

Selection of the design storm for sizing hydraulic structures is based on the level of acceptable risk of failure and the life of the facility. The product of these two factors gives the "return period" to be used in determining the design storm. For example, suppose a sediment basin is required to function on a site for two years and a 20% risk of failure of the facility is acceptable. This basin must be designed to capture the sediment from a 10-year storm (a 10-year storm has a 1/10 probability of occurring in one year and a 2/10 or 20% probability (1/10 + 1/10) of occurring during the two-year life of the example basin). Of course, the acceptable risk associated with proper functioning of the overflow spillway on the sedimentation basin would probably be much lower.

The duration of the design storm must also be specified, in addition to the return period. The duration of concern is determined by the type of hydraulic facility being designed. For a sedimentation basin, for example, the duration of interest might be several days to permit removal of the accumulated sediment before the next storm event. Simple conveyance-type facilities, such as swales or diversion dikes, would probably be designed for a shorter duration, often the concentration time for runoff in the upstream portion of the watershed.

Table I.C.2 shows the variation of design storm intensities within each of the nine Bay Area counties. The rainfall data were compiled from statistical analyses of local raingage records (California Department of Water Resources, 1976). To illustrate its usage, assume that the hypothetical sedimentation basin mentioned above is sited in Alameda County and that 3 days are considered adequate to recover from a storm

TABLE I.C.2 MAXIMUM RAINFALL INTENSITIES IN SAN FRANCISCO BAY AREA

Return Period	Maximum Precipitation in Inches for Indicated Duration		
	6 hour	24 hour	3 day
		San Mateo County	
10 yr.	1.35 - 2.65	2.27 - 5.05	3.32 - 5.92
25 yr.	1.63 - 3.18	2.73 - 6.04	4.06 - 7.23
50 yr.	1.83 - 3.57	3.06 - 6.77	4.60 - 8.20
100 yr.	2.02 - 3.95	3.38 - 7.49	5.14 - 9.15
		Contra Costa County	
10 yr.	1.89 - 3.27	2.44 - 6.16	3.64 - 8.02
25 yr.	2.24 - 3.93	2.91 - 7.40	4.36 - 9.81
50 yr.	2.50 - 4.41	3.24 - 8.30	4.88 - 11.12
100 yr.	2.75 - 4.88	3.56 - 9.18	5.38 - 12.40
		Marin County	
10 yr.	1.65 - 3.73	2.64 - 9.25	8.86 - 13.56
25 yr.	1.99 - 4.48	3.17 - 10.85	10.83 - 16.04
50 yr.	2.23 - 5.02	3.55 - 11.99	12.27 - 17.83
100 yr.	2.46 - 5.55	3.93 - 13.10	13.69 - 19.57
		Napa County	
10 yr.	3.01 - 3.46	3.60 - 7.07	5.71 - 11.44
25. yr.	3.58 - 4.16	4.32 - 8.50	6.98 - 13.98
50 yr.	3.99 - 4.66	4.85 - 9.53	7.92 - 15.84
100 yr.	4.38 - 5.16	5.36 - 10.54	8.83 - 17.68
		San Francisco	
10 yr.	1.66 - 1.96	2.62 - 3.40	5.18
25 yr.	1.99 - 2.35	3.15 - 4.08	6.33
50 yr.	2.24 - 2.63	3.54 - 4.58	7.18
100 yr.	2.47 - 2.91	3.91 - 5.06	8.01

TABLE I.C.2 continued

Return Period	Maximum Precipitation in Inches for Indicated Duration		
	6 hour	24 hour	3 day
		San Mateo County	
10 yr.	1.53 - 2.78	2.46 - 6.99	4.32 - 11.04
25 yr.	1.84 - 3.34	2.96 - 8.36	5.22 - 13.50
50 yr.	2.07 - 3.75	3.32 - 9.41	5.88 - 15.30
100 yr.	2.29 - 4.15	3.67 - 10.41	6.52 - 17.07
		Santa Clara County	
10 yr.	1.18 - 4.07	2.04 - 9.28	3.25 - 15.20
25 yr.	1.42 - 4.89	2.45 - 11.15	3.97 - 18.57
50 yr.	1.59 - 5.49	2.75 - 12.50	4.50 - 21.05
100 yr.	1.76 - 6.07	3.04 - 13.82	5.02 - 23.49
		Solano County	
10 yr.	1.95	2.26 - 6.34	3.25 - 9.74
25 yr.	2.35	2.65 - 7.54	3.85 - 11.73
50 yr.	2.63	2.93 - 8.41	4.29 - 13.16
100 yr.	2.91	3.20 - 9.24	4.71 - 14.55
		Sonoma County	
10 yr.	1.99 - 4.02	3.54 - 9.12	6.97 - 14.68
25 yr.	2.39 - 4.72	4.25 - 10.69	8.47 - 17.36
50 yr.	2.68 - 5.22	4.76 - 11.82	9.42 - 19.30
100 yr.	2.96 - 5.70	5.27 - 12.92	10.34 - 21.18

event. In Table I.C.2, under Alameda County on the row listing 10-year return period, the intensity range for the 3-day duration is a total of 3.3 to 5.9 inches of rain for the storm.

The ranges given in this table are county-wide and are not precise enough for site-specific designs. Rainfall intensity-duration-frequency data for the nearest raingage should be obtained from the California Department of Water Resource reference mentioned above. In addition to providing information based upon individual raingages, that source gives data for many other return periods and storm durations.

Sources and References

1. Amimoto, Perry Y. Erosion and Sediment Control Handbook. California Department of Conservation. May 1978.

2. California Department of Water Resources. Rainfall Analysis for Drainage Design, Volumes 1 and 2. Bulletin No. 195. October 1976.

3. Dunne, Thomas, and Luna B. Leopold. Water in Environmental Planning. W. H. Freeman and Co., San Francisco. 1978.

4. Flaxman, Elliot M. Predicting Sediment Yield in the Western United States. U.S. Department of Agriculture, Soil Conservation Service. December 1972.

5. Pacific Southwest Interagency Committee. Factors Affecting Sediment Yield and Measures for the Reduction of Erosion and Sediment Yield. October 1968.

6. U.S. Department of Agriculture, Soil Conservation Service. Guidelines for Erosion and Sediment Control in California. January 1975.

7. U.S. Department of Agriculture, Soil Conservation Service. Hydrology. National Engineering Handbook, Section 4. 1972.

8. U.S. Department of Agriculture, Soil Conservation Service. Procedure for Determining Rates of Land Damage, Land Depreciation and Volume of Sediment Produced by Gully Erosion. Technical Release No. 32. 1966.

D. STANDARDS AND SAMPLE SPECIFICATIONS FOR EROSION AND SEDIMENT CONTROL MEASURES

This Section contains standards and sample specifications for measures to control erosion and sediment on construction sites. They are intended to guide Bay Area cities and counties in developing their own standards and specifications, which should be adopted as a handbook and referenced in the local Erosion and Sediment Control Ordinance.

Such a handbook would have two uses. First, it would provide developers, design professionals and contractors with technical information needed to design and construct erosion and sediment control measures. Second, it would serve as a benchmark for staff of local planning and public works departments in assessing the adequacy of control measures proposed in the erosion and sediment control plans. When control measures different than those in the handbook are described in an erosion control plan for a project, the developer should be asked to justify his measures or to make them consistent with the handbook.

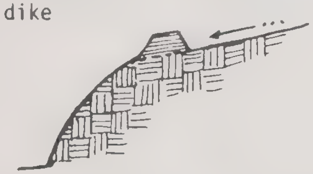
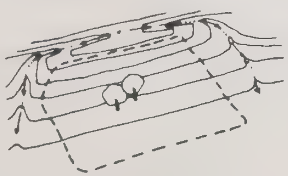
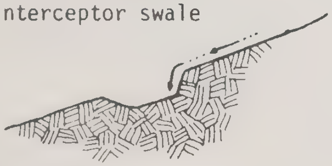
Table I.D.1 summarizes the erosion and sediment control measures and identifies common situations in which each of these measures is appropriate. (Note: The presence of a dot in a column opposite a control measure does not mean that the control measure can always be used to mitigate the problem shown. Conversely, the absence of a dot does not imply that the control measure can never be used for that problem. The table merely highlights typical applications.)

The standards and sample specifications in this section are interim recommendations intended for use in 1980-1981. During this period, they will be analyzed for their effectiveness in the Bay Area, and then further refined. They will be updated as new information becomes available.

Except for the standard for planting of exposed soils, which was prepared by ABAG, the following standards and sample specifications were adapted from California and nationwide SCS standards and specifications and from Standards and Specifications for Erosion and Sediment Control in Developing Areas (USDA, Soil Conservation Service, Maryland, 1975). Because of the variability of local and site-specific conditions (e.g., rainfall and soil conditions), all standards and sample specifications should be reviewed by a qualified professional before they are adopted by a local jurisdiction.

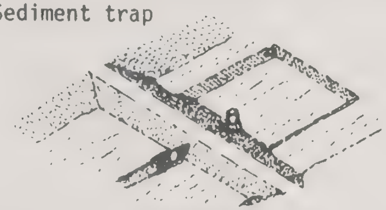
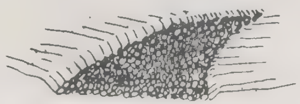
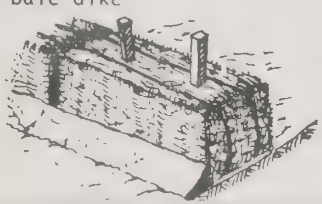
(Note: As used in this Chapter, a temporary control measure is installed during construction but is not intended to be part of the finished development. A temporary and permanent control measure is installed during construction and is, in addition, planned to be part of the finished development.)

Table I.D.1 Summary of Control Measure Applications

CONTROL MEASURE	PURPOSE	CONDITION NEEDING CONTROL: CUT SLOPES	FILL SLOPES	DENUDED GENTLY SLOPING OR FLAT AREA	ERODING STREAMBANK	ERODING SWALE	PROTECTION OF ADJACENT PROPERTY
Planting exposed soils 	To stabilize soils by absorbing the impact of raindrops, reducing velocity of runoff, and allowing precipitation to enter the soil.	●	●	●			●
Diversion dike and perimeter dike 	To intercept storm runoff from small upland areas and divert it from exposed slopes to an acceptable outlet.	○	●	●			●
Diversion 	To intercept and divert excess water from areas to sites where it can be disposed of safely.	●	○				●
Perimeter swale 	To prevent offsite runoff from entering a disturbed area and to prevent sediment-laden runoff from leaving the disturbed area.			●			●
Interceptor swale 	To shorten length of exposed slopes by intercepting runoff and diverting it to a stabilized outlet or sediment trap or basin.	○	●				●

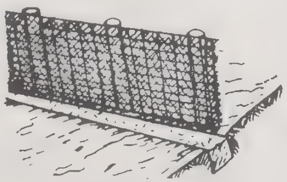
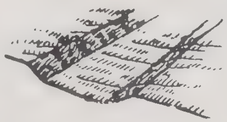
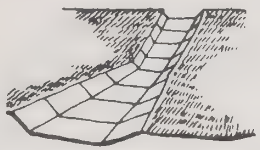
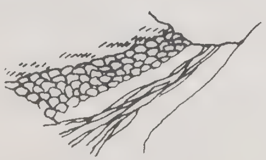
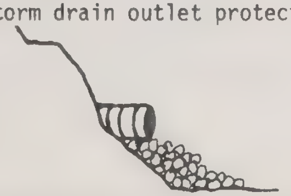
KEY: ● Preferred control measure ○ Alternative but less effective control measure.

Table I.D.1, cont. **Summary of Control Measure Applications**

CONTROL MEASURE	PURPOSE	CONDITION NEEDING CONTROL: CUT SLOPES	FILL SLOPES	DENUDED GENTLY SLOPING OR FLAT AREA	ERODING STREAMBANK	ERODING SWALE	PROTECTION OF ADJACENT PROPERTY
Grade stabilization structure 	To convey concentrated runoff safely down slopes without causing erosion	●	●				
Sediment basin 	To collect and store sediment and debris from construction sites.	●	●	●			●
Sediment trap 	To intercept sediment-laden runoff (small quantities) and trap the sediment.	○	○	●			●
Stabilized construction entrance 	To reduce the tracking or flowing of sediment onto public rights-of-way.						●
Straw bale dike 	To intercept and detain small amounts of sediment from small unprotected areas.			○			○

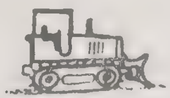
KEY: ● Preferred control measure ○ Alternative but less effective control measure

Table I.D.1, cont. Summary of Control Measure Applications

CONTROL MEASURE	PURPOSE	CONDITION NEEDING CONTROL					
		CUT SLOPES	FILL SLOPES	DENUDED GENTLY SLOPING OR FLAT AREA	ERODING STREAMBANK	ERODING SWALE	PROTECTION OF ADJACENT PROPERTY
Silt Fence 	To intercept and detain sediment from small unprotected areas			○			○
Grassed waterway 	To transport excess surface water without causing erosion or flooding				○	●	
Lined waterway or outlet 	To transfer or dispose of runoff without causing erosion, where unlined or grassed waterways would be inadequate				○	○	
Riprap 	To protect a soil surface or streambank from the erosive forces of water	○			●	●	
Storm drain outlet protection 	To convert pipe flow to channel flow and reduce water velocity so it can be conveyed down the channel without causing erosion				●	●	○

KEY: ● Preferred control measure ○ Alternative but less effective control measure.

Table I.D.1, cont. **Summary of Control Measure Applications**

CONTROL MEASURE	PURPOSE	CONDITION NEEDING CONTROL					
		CUT SLOPES	FILL SLOPES	DENUDED GENTLY SLOPING OR FLAT AREA	ERODING STREAMBANK	ERODING SWALE	PROTECTION OF ADJACENT PROPERTY
Land grading to minimize erosion 	To provide for erosion control and plant establishment on areas where topography is to be re-shaped by grading	●	●	●			●
Subsurface drain 	To intercept and prevent water movement into a wet area and remove runoff by collecting or conveying drainage water beneath the ground	○	○	○			○

KEY: ● Preferred control measure ○ Alternative but less effective control measure

STANDARDS AND SAMPLE SPECIFICATIONS FOR CONSTRUCTION SITE EROSION AND SEDIMENT CONTROL MEASURES

1. TEMPORARY AND PERMANENT PLANTING OF EXPOSED SOILS

STANDARD

Definition

Planting fast-growing vegetation, such as grasses, on erodible or eroding areas.

Purpose

To stabilize the soil by absorbing the impact of raindrops, reducing velocity of runoff and allowing precipitation to enter the soil; to provide both short- and long-term protection from erosion resulting from construction activities.

Scope

This practice applies to all areas where vegetation has been removed or disturbed due to construction activities.

Conditions Where This Practice Applies

This practice applies on areas denuded of vegetation by construction activities and on other highly erodible areas. Examples of applicable areas are cuts, fills, dams, dikes, levees and denuded or gullied areas. This practice does not apply to channels, swales, grassed waterways or other water conveyance structures (see Standard and Sample Specification for Grassed Waterway).

Design Considerations

1. The following should be considered when selecting the materials for planting of exposed areas:

   - erosion control effectiveness--fast growth, complete ground coverage, fibrous root mat;
   - commercial availability;
   - high drought tolerance;
   - low fire hazard;
   - low fertilizer requirements;
   - low application and maintenance costs.

2. Seeds should be planted in time to:

   - o germinate with the normally occurring light, early-season rains (0.5 to 1.0-inch storms);

   - o establish a root mat capable of resisting the erosive force of a 2.0-inch storm (approximately 30 days after germination);

   - o germinate and grow while temperatures are mild and daylight is relatively long (i.e., before November).

   Optimum time for planting is before September 15. Planting by September 15 provides a 98% probability that seeds will be in the ground in time for the first germination-causing rain, and a 90% probability that the first erosive rain will not occur for over 45 days.

   Planting by October 1 provides a 90% probability that seeds will be in the ground in time for the first germination-causing rain, and a 90% probability that the first erosive rain will not occur for over 30 days.

3. The surface to be seeded should be roughened or broken up so that it can hold seed and permit germination. If a graded area is to be seeded later, it should not be smoothed by grading equipment, but left in a rough or serrated condition.

4. The key factor in seeding is to cover the seeds with soil to the proper depth. Other factors to consider are slope, size of area to be seeded and soil depth.

   - o Small areas can best be hand-seeded to provide uniform coverage. Breast seeders ("belly-grinders") are inexpensive. Labor effort is 2-3 hours per acre.

   - o A seed drill works best on level areas. It should not be used on slopes greater than 3:1. When seed is drilled, fertilizer requirements may be reduced up to 50%.

   - o Hydroseeding/hydromulching is most efficient for seeding steep slopes and shallow soils (such as cut slopes and slopes steeper than 2:1). The critical factor in hydroseeding/hydromulching is the ability of seeds and mulch material to adhere to the soil.

5. Factors to consider for irrigating a planted area include:

   - o drought tolerance of planted vegetation;
   - o size of area;
   - o steepness of slope;
   - o cost;
   - o time of year;

- o equipment and technique;
- o frequency;
- o water availability.

Irrigation is expensive (about $1,000 per acre per month). It is not necessary when using drought tolerant species, unless the area is particularly critical (such as a steep, erodible slope above a water supply reservoir). Once begun, it should be continued until plant cover is fully established. Ceasing irrigation after germination leaves seedlings vulnerable to destruction by drought. Excessive irrigation or other improper irrigation practices can be harmful.

6. Application of mulch increases percentage of plant establishment and protects a disturbed site from erosive forces. Mulch helps hold fertilizer, seed and topsoil in place in the presence of wind, rain and runoff, and maintains moisture near the soil surface. Commonly used mulches include straw, wood fiber, wood chips or bark, fabric or mats, soil and gravel.

The choice of mulch should be determined based on:

- o effectiveness of materials;
- o size of area;
- o steepness of slope;
- o soil depth and surface hardness;
- o wind conditions;
- o availability of materials;
- o cost;
- o access to roadway and slope orientation (uphill or downhill);
- o fire hazard;
- o weed growth;
- o maintenance and repair costs.

Straw is the preferred mulch material:

- o on slopes of less than 2:1;
- o in large areas accessible by straw-blowing equipment within 50 feet;
- o on fill slopes;
- o in non-windy areas;
- o in downhill or downwind applications;
- o near agricultural areas where straw is produced;
- o where fire hazard and weed growth are not critical factors;
- o where repair and revegetation would be costly (straw mulch is highly effective and should not require maintenance if properly applied).

Hydromulch is the preferred mulch material:

- o in areas more than 50 feet from road access;
- o on slopes steeper than 2:1;
- o on cut slopes with shallow soil cover;
- o in windy areas;
- o where straw is not available;
- o where fire hazard or weed growth are critical factors.

While initial costs of applying hydromulch may be lower than costs of applying straw mulch, repair and maintenance requirements are often greater.

7. Slopes should be repaired and/or reseeded if the following conditions are observed:

   - o erosion on bare areas of slope;
   - o sheet or rill erosion has occurred;
   - o sediment buildup at toe of slope.

   If seeding is done long before September 15, seed loss caused by birds and wind may be significant. Thus, planting during September may reduce maintenance costs (see also (e) above).

Unit Cost Guide

$500-1,000 per acre (as of fall 1979).

Sources and References

This standard was prepared by ABAG based on the following sources:

1. U.S. Department of Agriculture, Soil Conservation Service.

2. Burgess Kay, Wildland Seeding Specialist, Department of Agronomy and Range Science, University of California, Davis.

3. Robert Crowell, Cagwin and Dorward Landscape Contractors and Engineers, San Rafael, California.

4. U.S. Department of Commerce, National Weather Service.

Design Plans and Specifications

Design plans and specifications for critical area planting should be in keeping with this standard and should describe the requirements for applying the practice to achieve its intended purpose.

SAMPLE SPECIFICATIONS FOR TEMPORARY AND PERMANENT PLANTING OF EXPOSED SOILS

Vegetation cannot be expected to provide erosion and sediment control unless soil conditions, seedbed preparation, species, seeding rates, fertilization and mulching are provided for as specified below.

1. The soil on the site must meet the following criteria:

   (a) The soil should contain no more than 70% sand (as defined by USDA, Soil Conservation Service). This is to provide enough available water-holding capacity to support plant growth.

   (b) The soil shall have sufficient porous base (greater than 30%) to permit adequate root penetration and provide for exchange of gases and water.

   (c) The soil shall be free from any material harmful to plant growth.

   If these conditions are not met, top soil must be brought in that will meet the conditions. When top soil is brought in, it should be disked into the existing soil to provide for a good bond.

2. The area to be seeded shall have a firm seedbed which has previously been roughened by scarifying, disking, harrowing, chiseling, track-walking or otherwise worked to a depth of 2 to 4 inches unless a roughened condition already exists. No implement shall be used that will create an excessive amount of downward movement of soil or clods on sloping areas. The seedbeds may be prepared at the time of completion of earth-moving work.

3. Seeding, fertilizing and mulching shall be done by September 15 of any year. Planting may be done earlier if irrigation is provided. If construction is not completed by October 1, temporary structural controls, such as sediment basins and sediment traps, may be used as interim control measures.

4. Based on availability, seeding species and application rates should be from one of the following:

(a)	Blando Brome	20 pounds per acre broadcast
	Zorro annual fescue	10 pounds per acre
	Wimmera 62 annual rye grass	20 pounds per acre
(b)	Zorro annual fescue	20 pounds per acre
	Rose clover	15 pounds per acre

(c) Luna or Topar pubescent wheat grass, or Tegmar intermediate wheat grass	40 pounds per acre broadcast or 20 pounds per acre drilled
(d) Palestine or Burber orchard grass	30 pounds per acre broadcast or 20 pounds per acre drilled
(e) Blando brome	10 pounds per acre broadcast or 5 pounds per acre drilled

All seed shall be delivered to the site tagged and labeled in accordance with the California Agricultural Code and shall be acceptable to the County Agricultural Commissioner.

Seed shall be of a quality which has a minimum pure live seed content of 80% (percent purity times percent germination), and weed seed shall not exceed 0.5% of the aggregate of pure live seed and other material. Zorro annual fescue shall have a minimum pure live seed content of 50% or more.

Seed shall be distributed uniformly over the seedbed by broadcasting by hand, using a hydroseeder or other approved equipment. Seed should be covered to a depth of one-quarter inch to one-half inch except when seed is applied by hydromulching. Seed shall not have a soil cover greater than 1 inch.

5. Fertilizer shall be distributed uniformly over the seedbed at a rate of not less than 500 pounds per acre. Fertilizer shall be applied in any way that will result in uniform distribution. Fertilizer shall be incorporated into the soil. Incorporation may be as part of the seedbed preparation or as part of the seeding operation. If fertilization is part of the seedbed preparation, it shall not be accomplished more than 15 days prior to seeding.

   The fertilizer shall contain a minimum of 16% nitrogen, 20% available phosphoric acid, 0% water soluble potash and 15% sulfur. It shall be uniform in composition, dry and free flowing, pelleted or granular.

   All fertilizer shall be delivered in unbroken or unopened containers, labeled in accordance with the applicable state regulations, and bearing the warranty of the producer for the grade furnished.

   Fertilizer may also be applied as a mix with seed and fiber in a slurry (see 7 below).

6. A mulch covering shall be distributed uniformly over the surface of the seeded area. Mulching shall follow immediately after seeding.

   Straw mulch shall be of unrotted small grain straw applied at the rate of 4,000 pounds per acre. Mulch materials shall be relatively free of all noxious weeds. The mulch shall be applied by hand, blower or other suitable equipment. If the straw is applied with a blower, it shall be chopped in lengths not less than 6 inches.

   The mulch will be anchored in place. The anchoring process may include using hand tools, mulching rollers, disks, nets, chemical tackifiers or other similar types of suitable equipment.

   The above is applicable to slopes flatter than 2:1. For slopes steeper than 2:1, hydromulching should be employed.

7. The hydromulching method calls for use of a hydroseeder to spread seed, fertilizer and mulch in a slurry.

   The hydroseeder shall be equipped with a built-in continuous agitation system of sufficient operating capacity to produce a homogeneous slurry and a discharge system that applies the slurry to the slopes at a continuous and uniform rate. Seed shall not remain in the slurry longer than 30 minutes. The slurry shall contain the required fertilizer and shall also contain wood fiber at the rate of 1,500 pounds of wood fiber per acre.

   The water used shall be potable water or Class 1 or 2 agricultural irrigation water.

   The slurry shall be continuously mixed and shall be mixed at least 5 minutes after the last addition before application starts. The slurry shall be applied at a rate that is nonerosive and minimizes runoff.

8. Irrigation is not required. If irrigation is selected, the following procedure shall be used. The surface inch of soil of all seeded areas shall be kept moist for the first 21 days after seeding. Moisture needs will be determined by visual observation. After 21 days the top 6 inches of soil shall be kept moist until the first major rainstorm (minimum 1.0 inch per 24 hour period). The moisture level will not be allowed to drop below 50% available moisture capacity.

   Irrigation applications shall not exceed:

   - 0.5 inch of water applied per acre per irrigation on sandy soils;

   - 1.0 inch of water applied per acre per irrigation on loamy and clayey soils.

Irrigation water shall be potable or Class 1 or 2 agricultural irrigation water. Water shall be applied by sprinklers or similar devices at a nonerosive rate using the above criteria as a guide.

9. Critical planting area sites shall be inspected no more than 30 days after planting and no more than 30 days after the first rain. Follow-up inspections should occur between 60 and 90 days after the first inspection and once again in the spring. If the site is well stabilized (not yielding sediment) in the spring inspection, no further inspection shall be necessary.

   If the spring inspection, or any other inspection, reveals that the slope needs to be repaired in that the seed has not taken or erosion has taken place, slopes shall be reseeded and/or repaired. The slope shall be smoothed over, including the filling of rills and/or gullies, before reseeding starts. The reseeding operation shall follow the specifications as given above.

Source and Reference

This specification was prepared from materials furnished by staff of the USDA, Soil Conservation Service and modified by ABAG for simplification and clarity.

2. TEMPORARY DIVERSION DIKE OR PERIMETER DIKE

STANDARD

Definition

Temporary ridge of compacted soil immediately above a cut or fill slope, constructed with sufficient grade to prevent drainage onto the slope.

Purpose

To intercept storm runoff from small upland areas and divert it from exposed slopes to an acceptable outlet; to prevent sediment-laden storm runoff from leaving the construction site or disturbed area.

Scope

This standard applies to all earth-fill structures constructed according to Earth Dams and Reservoirs (USDA, Soil Conservation Service, Technical Release No. 60, June 1976).

Conditions Where This Practice Applies

The diversion dike is used during the period of construction at the top of newly-constructed slopes. It remains in place until permanent drainage features are installed and/or slopes are stabilized.

Design Considerations

An engineered design is not required for diversion dikes and perimeter dikes. The following criteria should be considered:

- drainage area;
- top width and height;
- side slopes and grade;
- stabilization;
- outlet.

Unit Cost Guide

Dike: $2.00-$3.00 per linear foot (as of fall 1979).

Source and Reference

This standard was prepared from materials furnished by staff of the USDA, Soil Conservation Service and modified by ABAG for simplification and clarity.

Design Plans and Specifications

Design plans and specifications for installing diversion dikes and perimeter dikes should be in keeping with this standard and should describe the requirements for applying the practice to achieve its intended purpose.

SAMPLE SPECIFICATIONS FOR DIVERSION DIKE OR PERIMETER DIKE

Design Specifications

1. The drainage area shall be less than 5 acres (for larger drainage areas see Standard and Sample Specifications for Permanent Diversion).

2. The top width shall be 2 feet minimum.

3. The height (compacted fill) shall be a minimum of 18 inches measured from the existing ground at the upslope toe to the top of the dike; 30 inches maximum height.

4. The side slopes shall be 2:1 or flatter.

5. The grade shall be dependent upon topography, but must have positive drainage (sufficient grade to drain) to an adequate outlet.

6. Where slope of channel (flow area) is:

   (a) 0% - 5%, stabilization may be required by the designer according to the needs of the site;

   (b) over 5%, stabilization shall be required.

   Stabilization shall be:

   (a) in accordance with the Standard and Sample Specification for Grassed Waterway; or

   (b) by lining the flow area with stone that meets MSHA size No. 2 or AASHTO M43 size No. 2 or 24 in a layer at least 3 inches thick and pressed into the soil. The lining shall extend up the upslope side of the dike to a height of at least 8 inches measured vertically from the upslope toe and shall extend at least 7 feet upslope from the upslope toe.

7. Diverted runoff from:

   (a) a protected or stabilized area shall outlet directly to an undisturbed stabilized area or into a level spreader or grade stabilization structure;

   (b) a disturbed or exposed upland area shall be conveyed to a sediment-trapping device such as a sediment trap or a sediment basin or to an area protected by any of these practices.

Construction Specifications

1. All dikes shall be machine compacted with the tires or tracks going over at least 90% of the surface. There shall be a maximum of 6 inches of lift between each compaction.

2. All diversion dikes shall have positive drainage to an adequate outlet.

3. Diverted runoff from:

   (a) a protected or stabilized area shall outlet directly to an undisturbed stabilized area or into a level spreader or grade stabilization structure;

   (b) a disturbed or exposed upland area shall be conveyed to a sediment-trapping device such as a sediment trap or a sediment basin or to an area protected by any of these practices.

4. Stabilization, as specified by the plans, shall be:

   (a) in accordance with the Standard and Sample Specifications for Grassed Waterway, and the area to be stabilized shall be the channel (flow area); or

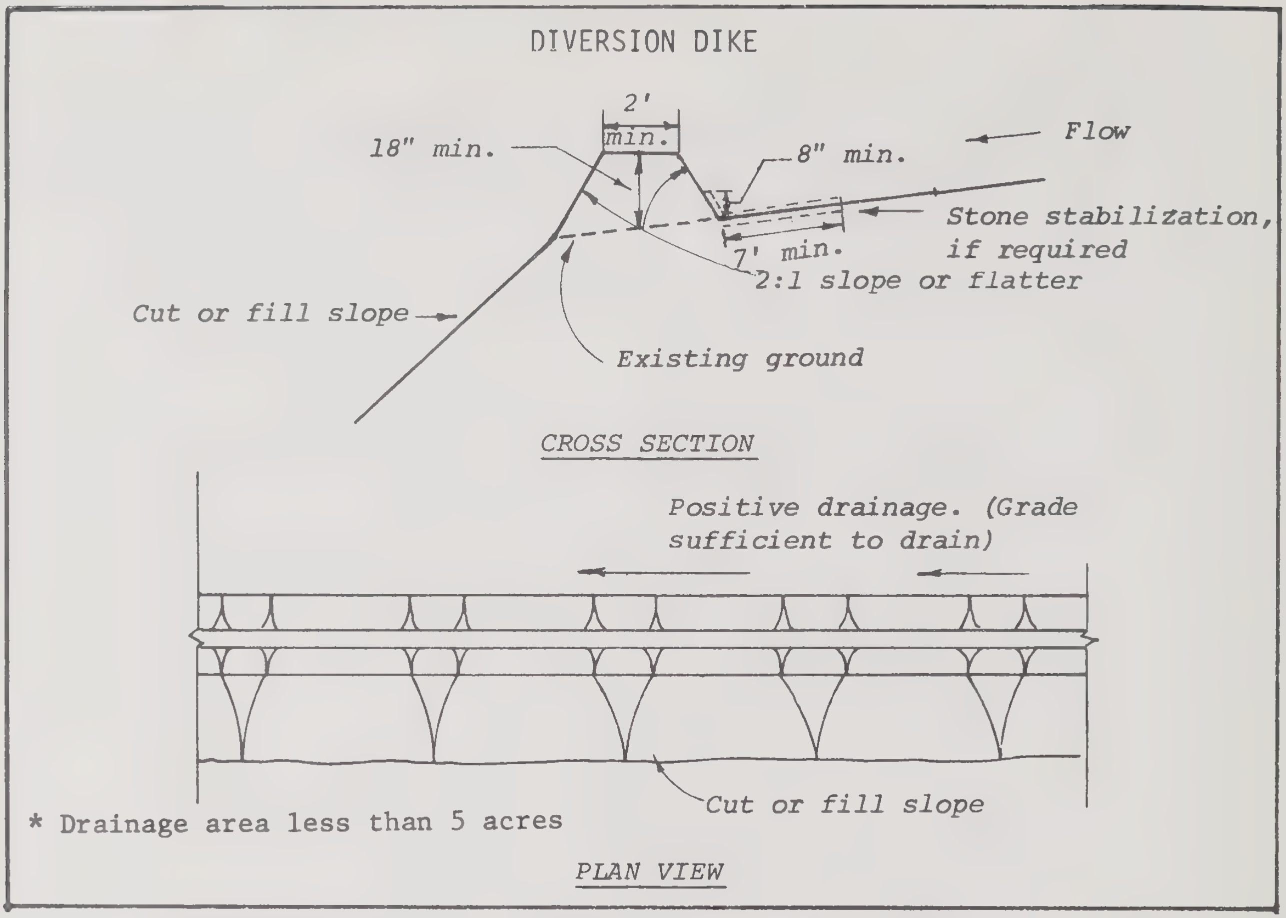
   (b) by lining the flow area with stone that meets MSHA size No. 2 or AASHTO M43 size No. 2 or 24, in a layer at least 3 inches thick and pressed into the soil.

5. Periodic inspection and required maintenance shall be provided.

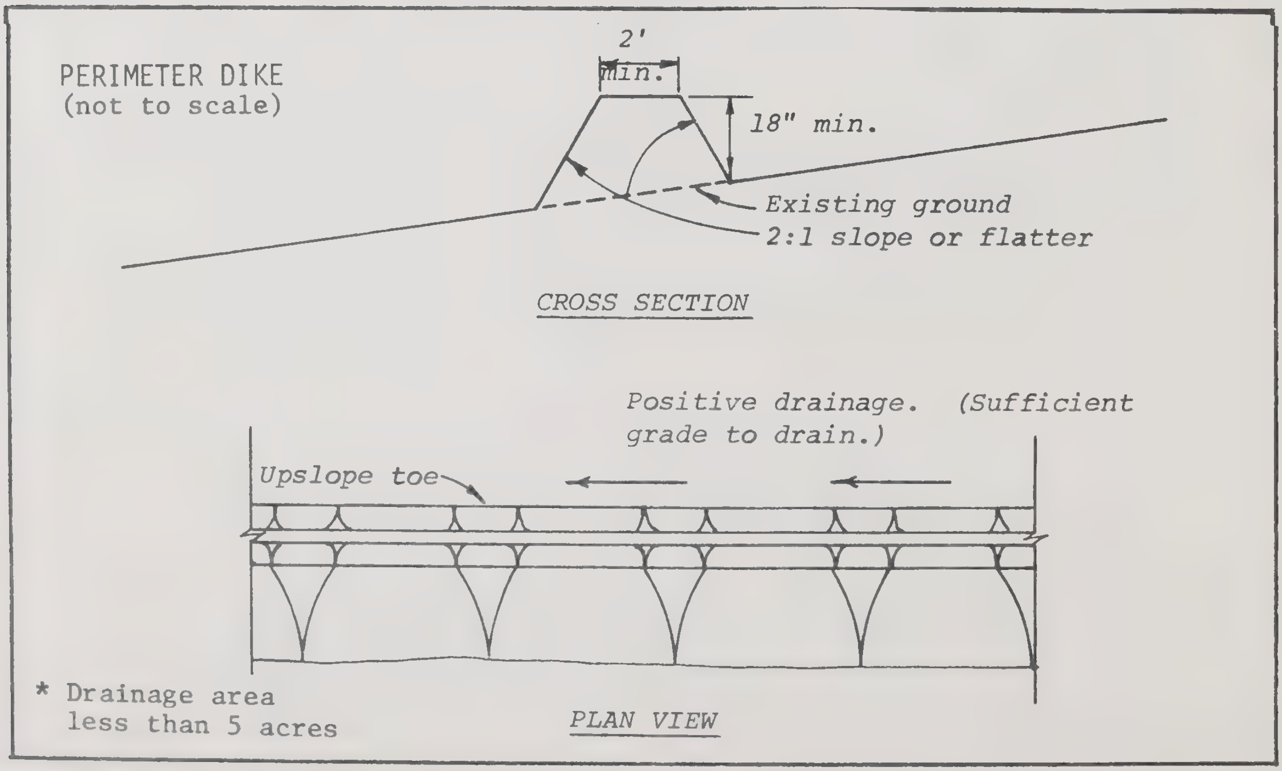
Source and Reference

This specification was prepared from materials furnished by staff of the USDA, Soil Conservation Service and modified by ABAG for simplification and clarity.

Sample Drawing: Diversion Dike*



Sample Drawing: Perimeter Dike*



(adapted from USDA, Soil Conservation Service, College Park, Maryland. Standards and Specifications for Soil Erosion and Sediment Control in Developing Areas. July 1975.)

3. PERMANENT DIVERSION

STANDARD

Definition

A channel with a supporting ridge on the lower side; constructed across the slope.

Purpose

To intercept and divert excess water away from highly erodible areas to sites where it can be used or disposed of safely.

Scope

This standard applies to the installation of all diversions except flood water diversions.

Conditions Where This Practice Applies

Diversions are used where:

- runoff from higher areas is causing or could cause erosion or damage to property or is interfering with or preventing the establishment of vegetation on lower areas;
- surface and shallow subsurface flow caused by seepage is damaging upland slopes;
- runoff is in excess and available for diversion and use on nearby sites;
- a diversion is required as part of a pollution abatement system;
- a diversion is required to control erosion and runoff on urban and developing areas and construction sites.

In all of the above, the length of slopes should be reduced to minimize soil loss. Diversions should not be substituted for terraces on land requiring terracing for erosion control, nor should they be used on slopes greater than 15%. Diversions should not be used below high sediment-producing areas unless land-treatment practices or structural measures designed to prevent damaging accumulations of sediment in the channels are installed.

Design Considerations

Design considerations should include the following:

- o capacity;
- o cross-section;
- o grade and velocity;
- o location;
- o protection against sedimentation;
- o outlets;
- o vegetation;
- o maintenance requirements.

Unit Cost Guide

$20.00-$25.00 per linear foot (as of fall 1979).

Source and Reference

This standard was prepared from materials furnished by staff of the USDA, Soil Conservation Service and modified by ABAG for simplification and clarity.

Design Plans and Specifications

Design plans and specifications for installing diversions should be in keeping with this standard and should describe the requirements for applying the practice to achieve its intended purpose.

SAMPLE SPECIFICATIONS FOR PERMANENT DIVERSION

Design Specifications

1. The constructed diversion shall have the capacity to carry, as a minimum, the peak discharge from a 10-year-frequency rainfall event with a freeboard not less than 0.3 foot. Diversions designed to protect urban areas, buildings and roads, and those designed to function in connection with other structures shall have enough capacity to carry the peak runoff expected from a storm frequency consistent with the hazard involved.

2. The channel cross-section may be parabolic, V-shaped or trapezoidal. The diversion shall be designed to have stable side slopes and shall not be steeper than 2:1 and shall be flat enough to ensure ease of maintenance of the structure and its protective vegetative cover. The ridge height shall include a reasonable settlement factor. The ridge shall have a minimum top width of 4 feet at the design elevation. The minimum cross-section shall meet the specified dimensions. The top of the constructed ridge shall not be lower at any point than the design elevation plus specified overfill for settlement. A minimum of 0.3 foot freeboard will be provided.

3. Channel grades may be uniform or variable. Channel velocity shall not exceed that considered nonerosive for the soil and planned treatment.

4. The location of the diversion shall be determined by outlet conditions, topography, land use, cultural operations, soil type, seep planes (when seepage is a problem) and length of slope in the development layout.

5. If movement of sediment into the channel is a significant problem, a vegetated filter strip shall be used except where soil and/or climate preclude the use of such strips. Then, the design shall include extra capacity for sediment and be supported by supplemental structures, cultural or tillage practices, or special maintenance measures.

6. Each diversion must have an adequate outlet. The outlet may be a grassed waterway, a vegetated or paved area, a grade stabilization structure, a stable watercourse or an underground outlet. The outlet must convey runoff to a point where outflow will not cause damage. Vegetated outlets shall be installed before the diversion construction to ensure establishment of vegetative cover in the outlet channel. Underground outlets consist of inlet and underground conduit, and the release rate when combined with a storage is to be such that the design storm will not overtop the diversion ridge.

To prevent ponding in the diversion, the design elevation of the water surface in the diversion shall not be lower than the design elevation of the water surface in the outlet at their junction when both are operating at design flow.

7. Disturbed areas shall be established to grass as soon as practicable after construction. Vegetative cover shall comply with recommendations in the Sample Specifications for Grassed Waterway.

   (a) For design velocities of less than 3.5 feet per second, seeding and mulching may be used for the establishment of the vegetation. It is recommended that, when conditions permit, temporary diversions or other means be used to prevent water from entering the diversion during the establishment of the vegetation.

   (b) For design velocities of more than 3.5 feet per second, the diversion shall be stabilized with sod, with seeding protected by jute or excelsior matting or with seeding and mulching including temporary diversion of water until the vegetation is established. See Appendix A, Standard and Specifications for Protective Materials for Channels and Steep Slopes.

   For recommendations on seedbed preparation, seeding, fertilizing and mulching, consult the local office of the Soil Conservation Service. If the soils or climatic conditions preclude the use of vegetation and protection is needed, nonvegetative means, such as mulches or gravel, may be used.

Construction Specifications

1. The foundation area for the embankment or ridge shall be stripped of all vegetation, brush or other objectionable material. Small gullies, ditches or depressions within the foundation area shall be filled and compacted. This will prevent interference with the proper functioning of the diversion.

2. The channel shall be excavated to the neat lines and grades shown on the plans and/or as staked in the field. Excavated materials shall be used in the earth embankment or wasted to selected locations. Borrow shall be obtained at locations specified or shown on the drawings.

3. If underground conduits are located under diversion ridges, mechanical compaction, water packing and installation and backfill of conduit trenches shall be made in advance to allow adequate settlement. Materials used for the inlet and conduit shall be suitable for the purpose intended and shall meet the requirements as recommended under Standard and Sample Specifications for Subsurface Drains.

4. Fill material shall meet the following criteria:

   (a) All satisfactory fill material obtained from the excavated channel will be used to construct the embankment. Fill material containing brush, roots, or other perishable or unsuitable materials shall not be used. Cobbles and rock fragments having a maximum dimension of more than 6 inches will be removed from the material. Gravel and sand will not be used to construct the fill unless mixed with clay material approved by the engineer.

   (b) The soil moisture of fill material shall be such that the material will form a firm ball when squeezed in the hand.

   Compaction may be accomplished by the passage of the excavating equipment. The wheels or tracks of the excavating equipment must pass over 90% of the surface of each lift. Each lift shall not exceed 6 inches before compaction. Diversion ridges constructed across gullies or depressions shall also be compacted in the above-stated manner. The surface of the finished diversion shall be reasonably smooth and present a workmanlike appearance.

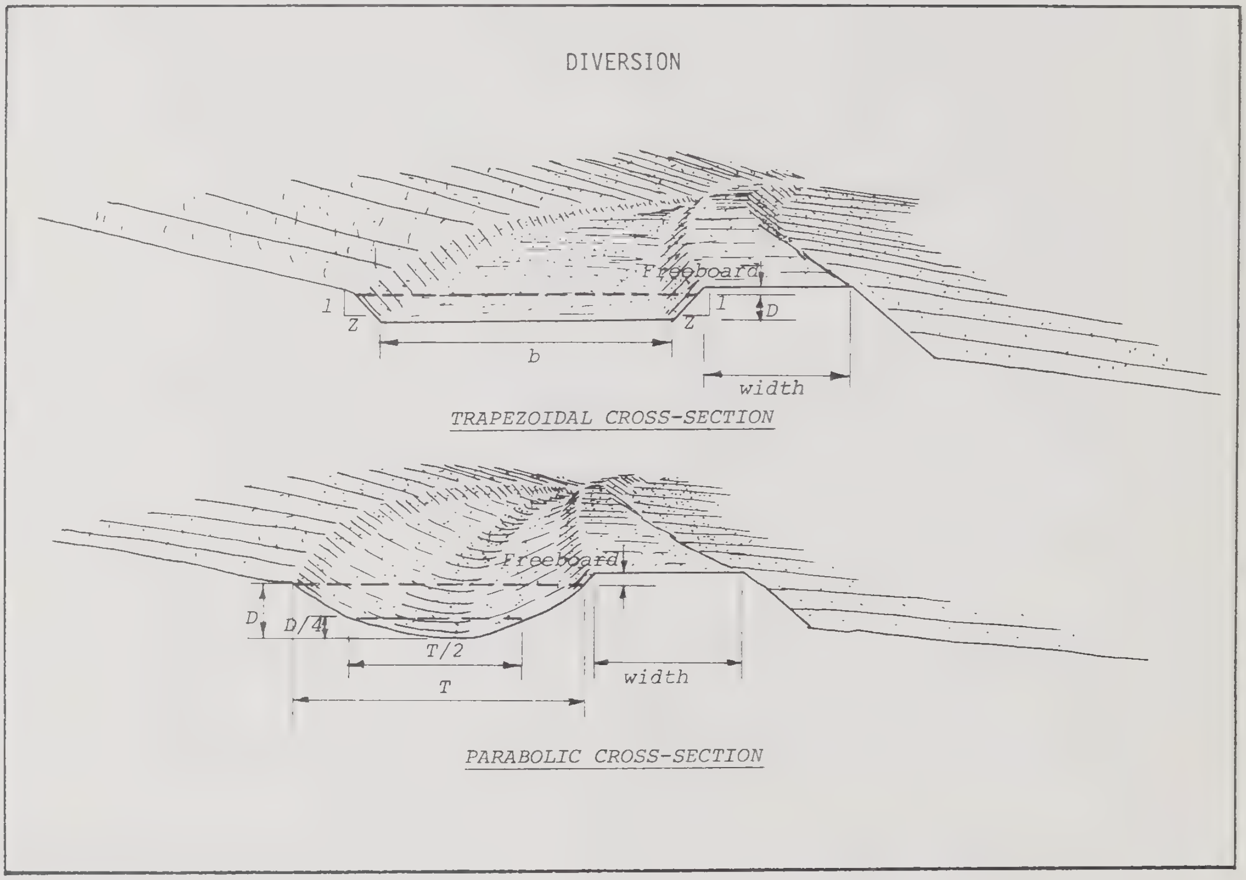
5. A protective covering shall be established on all of the disturbed areas to the extent practicable under prevailing soil and climate conditions. Care will be taken during construction to avoid disturbance of vegetation outside the channel or embankment area. If it is necessary, top soil shall be stockpiled and spread over the excavations and other areas to facilitate revegetation.

6. A maintenance program should be established to maintain diversion capacity, storage, ridge height and the outlets. Any hazards must be brought to the attention of the responsible person.

<u>Source and Reference</u>

This specification was prepared from materials furnished by staff of the USDA, Soil Conservation Service and modified by ABAG for simplification and clarity.

Sample Drawing: Diversion



(adapted from USDA, Soil Conservation Service, College Park, Maryland. Standards and Specifications for Soil Erosion and Sediment Control in Developing Areas. July 1975.)

4. TEMPORARY PERIMETER SWALE

STANDARD

Definition

A temporary excavated drainageway constructed along the perimeter of a site or disturbed area.

Purpose

To intercept storm runoff and to prevent it from entering a disturbed area and/or to prevent sedement-laden storm runoff from leaving a disturbed area.

Scope

This standard applies to all temporary perimeter swales draining an area of less than 5 acres.

Conditions Where This Practice Applies

The perimeter swale is used during the period of construction at the perimeter of disturbed areas, where storm runoff would enter or leave the site. The swale remains in place until the disturbed area is permanently stabilized. Runoff diverted from the disturbed area should be adequately handled to prevent flooding or erosion damage to adjacent property. The swale will be removed when the disturbed area is permanently stabilized.

Design Considerations

Design considerations should include the following:

- o location and possible permits necessary for construction;
- o drainage area;
- o bottom width;
- o depth;
- o side slope;
- o grade;
- o stabilization;
- o outlet.

Unit Cost Guide

$8.00-$15.00 per cubic yard (as of fall 1979), depending on base material.

Source and Reference

This standard was prepared from materials furnished by staff of the USDA, Soil Conservation Service and modified by ABAG for simplification and clarity.

Design Plans and Specifications

Design plans and specifications for installing perimeter swales should be in keeping with this standard and should describe the requirements for applying the practice to achieve its intended purpose.

SAMPLE SPECIFICATIONS FOR TEMPORARY PERIMETER SWALE

Design Specifications

1. The drainage area shall be less than 5 acres (for larger drainage areas, see Standard and Sample Specifications for Diversion or Grassed Waterway).

2. The bottom width shall be a minimum of 7 feet and the bottom shall be level.

3. The depth shall be a minimum of 1 foot.

4. The side slope shall be 2:1 or flatter (flat enough to allow construction traffic to cross if desired).

5. The grade shall be dependent on topography, which shall have a minimum grade of 1% to an adequate outlet.

6. Where the slope of the channel (flow area) is 1% to 5%, stabilization may be required by the designer according to the needs of the site. Where the slope of the channel is greater than 5%, stabilization shall be required.

   Stabilization shall be:

   (a) in accordance with the Standard and Sample Specifications for Grassed Waterway; or

   (b) by lining the flow area with stone that meets MSHA No. 2 or AASHTO M43 size No. 2 or 24 in a layer at least 3 inches thick and pressed into the soil. The lining shall extend across the bottom and up both sides of the channel to a height at least 8 inches vertically above the bottom.

7. At all points where several vehicle crossings per day will be made, the swale shall be stabilized according to (b) above, except that the stone lining shall be at least 6 inches thick for the whole width of the traffic crossing.

8. Diverted runoff from:

   (a) a protected or stabilized upland area shall outlet directly onto an undisturbed stabilized area or into a level spreader or grade stabilization structure;

(b) a disturbed or exposed upland area shall be conveyed to a sediment-trapping device such as a sediment trap or a sediment basin or to an area protected by any of these practices.

Construction Specifications

1. All trees, brush, stumps, obstructions and other objectionable material shall be removed and disposed of so as not to interfere with the proper functioning of the swale.

2. The swale shall be excavated and/or shaped to line, grade and cross-section as required to meet the criteria specified herein, and be free of bank projections or other irregularities which will impede normal flow.

3. Fills shall be compacted as needed to prevent unequal settlement that would cause damage in the completed swale.

4. All earth removed and not needed in construction shall be spread or disposed of so it will not interfere with the functioning of the swale.

5. Perimeter swales shall have a minimum grade of 1% and the bottom shall be level.

6. Diverted runoff from:

   (a) a protected or stabilized upland area shall outlet directly onto an undisturbed stabilized area, or into a level spreader or grade stabilization structure;

   (b) a disturbed or exposed upland area shall be conveyed to a sediment-trapping device such as a sediment trap or sediment basin, or to an area protected by any of these practices.

7. Stabilization shall be:

   (a) in accordance with the Standard and Sample Specifications for Grassed Waterway; or

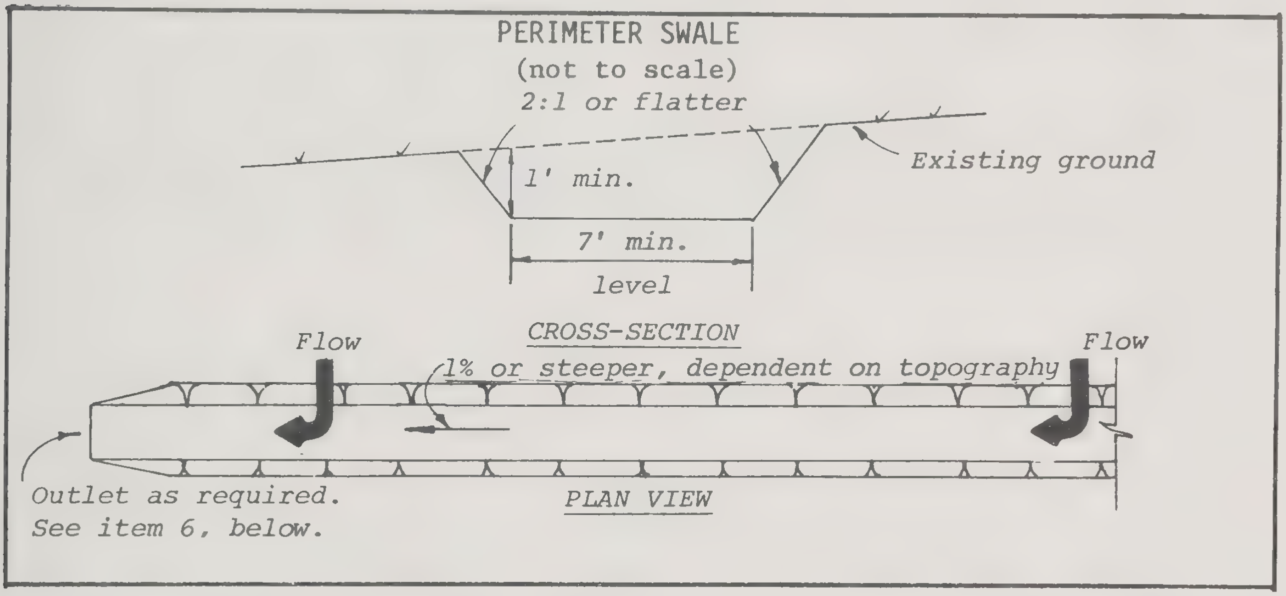
   (b) by lining the flow area with stone that meets MSHA size No. 2 or AASHTO M43 size No. 2 or 24 in a layer at least 3 inches thick and pressed into the soil. The lining shall extend across the bottom and up both sides of the channel to a height at least 8 inches measured vertically from the bottom.

8. Periodic inspection and required maintenance shall be provided to ensure that the perimeter swale is functioning properly.

Source and Reference

This specification was prepared from materials furnished by staff of the USDA, Soil Conservation Service and modified by ABAG for simplification and clarity.

Sample Drawing: Perimeter Swale



(adapted from USDA, Soil Conservation Service, College Park, Maryland. Standards and Specifications for Soil Erosion and Sediment Control in Developing Areas. July 1975.)

5. TEMPORARY INTERCEPTOR SWALE

STANDARD

Definition

A temporary excavated drainageway constructed across disturbed areas or rights-of-way.

Purpose

To shorten the length of exposed slopes, thereby reducing the potential for erosion, by intercepting storm runoff and diverting it to a stabilized outlet or sediment-trapping device.

Scope

This standard applies to all interceptor swales draining areas of less than 5 acres.

Conditions Where This Practice Applies

Interceptor swales are constructed across disturbed areas such as rights-of-way for pipe lines and streets, graded parking lots and land fills. The swale remains in place until the disturbed area is permanently stabilized.

Design Considerations

Design considerations should include the following:

- o drainage area;
- o bottom width;
- o depth;
- o side slopes;
- o grade;
- o stabilization;
- o traffic crossings;
- o spacing between swales.

An interceptor swale should have an outlet that functions with a minimum of erosion.

Runoff should be conveyed to a sediment-trapping device such as a sediment trap or sediment basin.

The on-site location may need to be adjusted so that the most suitable outlet can be used.

Unit Cost Guide

$8.00-$15.00 per cubic yard (as of fall 1979), depending on the base material.

Source and Reference

This standard was prepared from materials furnished by staff of USDA, Soil Conservation Service and modified by ABAG for simplification and clarity.

Design Plans and Specifications

Design plans and specifications for interceptor swales should be in keeping with this standard and should describe the requirements for applying the practice to achieve its intended purpose.

SAMPLE SPECIFICATIONS FOR TEMPORARY INTERCEPTOR SWALE

Design Specifications

1. The drainage area shall be less than 5 acres (for larger drainage areas see Standard and Sample Specifications for Grassed Waterway).

2. The bottom width shall be a minimum of 7 feet and the bottom shall be level.

3. The depth shall be 1 foot minimum.

4. The side slopes shall be 2:1 or flatter (flat enough to allow construction traffic to cross if desired).

5. The grade shall be 1% to 3% (sufficient grade to drain) to an adequate outlet. Drainage must be positive.

6. Stabilization is not required by this standard, but may be required by the designer according to the needs of the site. Stabilization shall be:

   (a) in accordance with the Standard and Sample Specifications for Grassed Waterway; or

   (b) by lining the flow area with stone that meets MSHA size No. 2 or AASHTO M43 size No. 2 or 24 in a layer at least 3 inches thick and pressed into the soil. The lining shall extend across the bottom and up both sides of the channel to a height of at least 8 inches measured vertically from the bottom.

7. At all points where several vehicle crossings per day will be made, the swale shall be stabilized according to (b) above, except that the stone lining shall be at least 6 inches thick for the full width of the traffic crossing.

8. If the slope of the right-of-way or disturbed area is greater than 10%, then the maximum distance between swales shall be 100 feet. If the slope is between 5% and 10%, the maximum distance shall be 200 feet. If the slope is less than 5%, the maximum distance shall be 300 feet.

Construction Specifications

1. All trees, brush, stumps, obstructions and other objectionable material shall be removed and disposed of so as not to interfere with the proper functioning of the swale.

2. The swale shall be excavated and/or shaped to line, grade and cross-section as required to meet the criteria specified herein and be free of bank projections or other irregularities which will impede normal flow.

3. Fills shall be compacted as needed to prevent unequal settlement that would cause damage in the completed swale.

4. All earth removed and not needed in construction shall be spread or disposed of so that it will not interfere with the functioning of the swale.

5. Interceptor swales shall have a minimum grade of 1% and the bottom shall be level.

6. An interceptor swale shall have an outlet that functions with a minimum of erosion.

7. Runoff shall be conveyed to a sediment-trapping device such as a sediment trap or a sediment basin.

8. The on-site location may need to be adjusted to meet field conditions in order to utilize the most suitable outlet.

9. Stabilization shall be:

   (a) in accordance with the Standard and Sample Specifications for Grassed Waterways; or

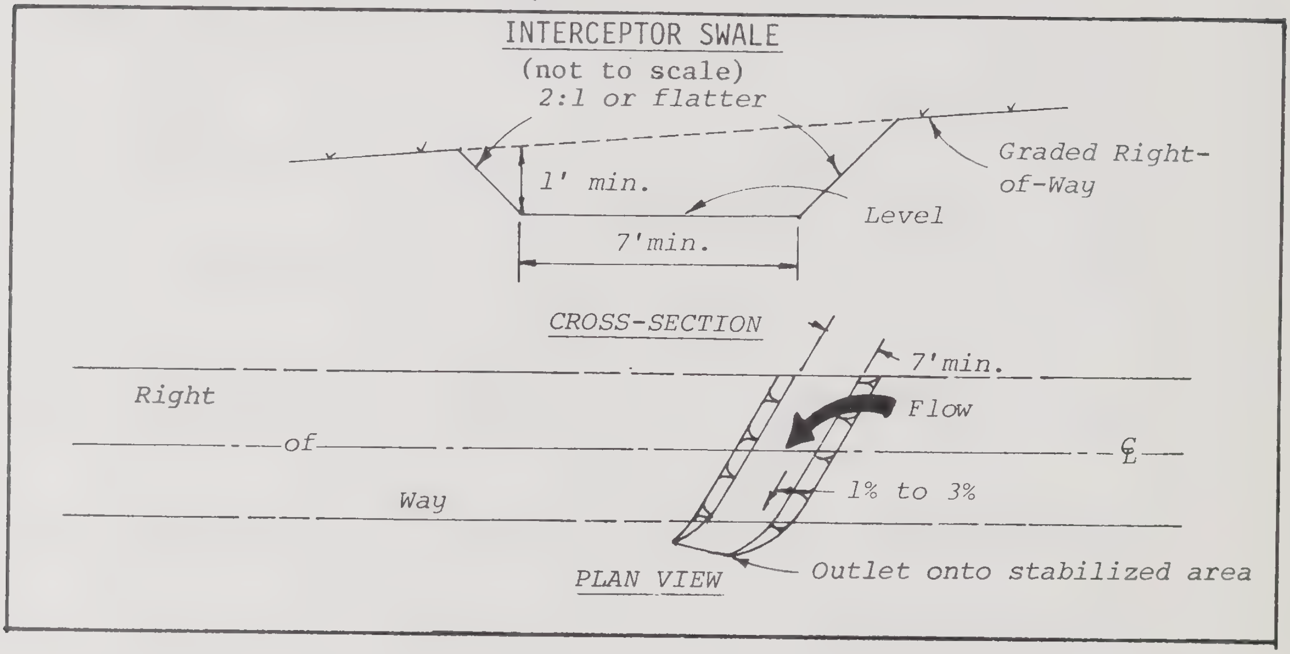
   (b) by lining the flow area with a stone layer that meets MSHA size No. 2 or AASHTO M43 size No. 2 or 24 in a layer at least 3 inches thick and pressed into the soil. The lining shall extend across the bottom and up both sides of the channel to a height of at least 8 inches measured vertically from the bottom.

10. Periodic inspection and required maintenance shall be provided.

Source and Reference

This specification was prepared from materials furnished by staff of the USDA, Soil Conservation Service and modified by ABAG for simplification and clarity.

Sample Drawing: Interceptor Swale



(adapted from USDA, Soil Conservation Service, College Park, Maryland. Standards and Specifications for Soil Erosion and Sediment Control in Developing Areas. July 1975.)

6. TEMPORARY GRADE STABILIZATION STRUCTURE

STANDARD

Definition

A temporary channel constructed of nonerodible material extending from the top to the bottom of a slope.

Purpose

To convey concentrated surface runoff down slopes without causing erosion.

Scope

This standard applies to all types of grade stabilization structures up to a maximum drainage area of 36 acres. (For drainage areas of less than 5 acres, see specifications for pipe slope drain. For drainage areas between 5 and 36 acres, see specifications for paved chute or flume.)

Conditions Where This Practice Applies

Grade stabilization structures are used where the concentration and flow velocity of water are such that structures are needed to stabilize the grade in channels or to control gully erosion.

Unit Cost Guide

Variable, depending on materials, local topography and size.

Source and Reference

This standard was prepared from materials furnished by staff of the USDA, Soil Conservation Service and modified by ABAG for simplification and clarity.

Design Plans and Specifications

Design plans and specifications for constructing grade stabilization structures should be in keeping with this standard and should describe the requirements for applying the practice to achieve its intended purpose.

SAMPLE SPECIFICATIONS FOR TEMPORARY GRADE STABILIZATION STRUCTURE

Design Specifications

The quality of the materials shall be adequate to provide the stability and durability required to achieve the planned objective with appropriate factors of safety. A pipe slope drain or a paved chute or flume shall be used to convey surface runoff safely down slopes without causing erosion. The maximum allowable drainage area shall be 5 acres for a pipe slope drain, and shall be 36 acres for a paved chute or flume.

Pipe Slope Drain

1. Pipe slope drains are to be used as follows:

Size	Pipe/Tubing Diameter, D, (Inches)	Maximum Drainage Area (Acres)
PSD-12	12	0.5
PSD-18	18	1.5
PSD-21	21	2.5
PSD-24	24	3.5
PSD-30	30	5.0

(Note: These pipe size specifications are examples only. The pipe dimensions for each project should be calculated by a qualified engineer based on local conditions.)

2. The height of the earth dike at the entrance to the pipe slope drain shall be equal to or greater than the diameter of the pipe, D+12 inches (see sample drawings).

3. The pipe slope drain shall outlet onto a riprap apron and then into a stabilized area or stable water course. A sediment-trapping device shall be used to trap sediment from any sediment-laden water conveyed by the pipe slope drain.

Paved Chute or Flume

1. Size Group A

The height (H) of the dike at the entrance is at least 1.5 feet. The depth (D) of the chute down the slope is at least 8 inches. The length (L) of the inlet and outlet sections is 5 feet.

Size Group B

The height (H) of the dike at the entrance is at least 2 feet. The depth (D) of the chute down the slope is at least 10 inches. The length (L) of the inlet and outlet sections is 6 feet.

Each size group has various bottom widths and allowable drainage areas as shown below:

Size*	Bottom Width B, (Feet)	Maximum Drainage Area (Acres)	Size*	Bottom Width B, (Feet)	Maximum Drainage Area (Acres)
A-2	2	5	B-4	4	14
A-4	4	8	B-6	6	20
A-6	6	11	B-8	8	25
A-8	8	14	B-10	10	31
A-10	10	18	B-12	12	36

(Note: These chute and flume size specifications are examples only. The chute or flume dimensions for each project should be calculated by a qualified engineer based on local conditions.)

*The size is designated with a letter and a number, such as A-6, which means a chute or flume is size group A with a 6 foot bottom width. The selected size shall be shown on the plans.

2. When a paved chute or flume of size group B is used, the velocity at its outfall shall be checked for erosion potential downstream.

Construction Specifications - Rigid Pipe Slope Drain

1. The inlet pipe shall have a slope of 3% or steeper.

2. The top of the earth dike over the inlet pipe, and those dikes carrying water to the pipe, shall be at least 1 foot higher at all points than the top of the inlet pipe.

3. The pipe shall be corrugated metal pipe with water-tight connecting bands.

4. A riprap apron shall be provided at the outlet. This shall consist of 6-inch diameter stone placed as shown on the sample drawing.

5. The soil around and under the inlet pipe and entrance section shall be hand-tamped in 4-inch lifts to the top of the earth dike.

6. Follow up inspection and any needed maintenance shall be performed after each storm.

Construction Specifications - Flexibile Pipe Slope Drain

1. The inlet pipe shall have a slope of 3% or steeper.

2. The top of the earth dike over the inlet pipe, and those dikes carrying water to the pipe, shall be at least 1 foot higher at all points than the top of the inlet pipe.

3. The inlet pipe shall be corrugated metal pipe with water-tight connecting bands.

4. The flexible tubing shall be the same diameter as the inlet pipe and shall be constructed of durable material with hold-down grommets spaced 10 feet on centers.

5. The flexible tubing shall be securely fastened to the corrugated metal pipe with metal strapping or water-tight collars.

6. The flexible tubing shall be securely anchored to the slope by staking at grommets provided.

7. A riprap apron shall be provided at the outlet. This shall consist of 6-inch diameter stone placed as shown on the sample drawings.

8. The soil around and under the inlet pipe and entrance section shall be hand-tamped in 4-inch lifts to the top of the earth dike.

9. Follow-up inspection and any needed maintenance shall be performed after each storm.

Construction Specifications - Paved Chute or Flume

1. The structure shall be placed on undisturbed soil or on well compacted fill.

2. The cut or fill slope shall not be steeper than 2:1 and shall not be flatter than 20:1.

3. The top of the earth dike at the entrance, and those dikes carrying water to it, shall not be lower at any point than the top of the lining at the entrance of the structure.

4. The lining at the entrance to the structure shall extend the distance H above the lining crest shown on the sample drawings.

5. The lining shall be placed beginning at the lower end and proceeding up the slope to the upper end. The lining shall be well compacted and free of voids. The lining surface shall be reasonably smooth.

6. The entrance floor at the upper end of the structure shall have a slope toward the outlet of one-quarter to one-half inch per foot.

7. The cut-off walls at the entrance and at the end of the discharge aprons shall be continuous with the lining.

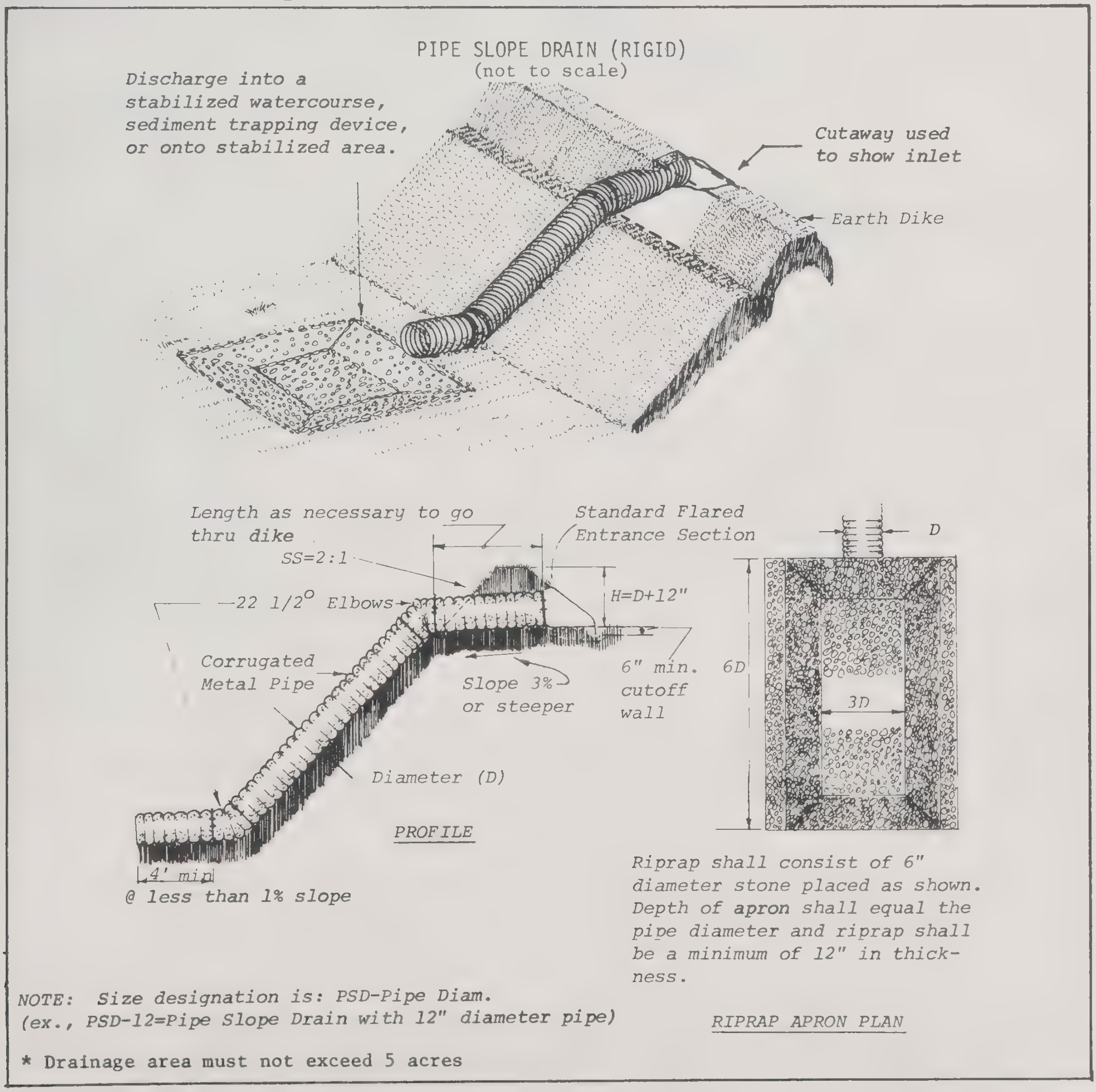
8. The lining shall consist of Type 2 Portland cement concrete (3,000 psi), Bituminous concrete or comparable nonerodible material.

9. An energy dissipator of adequate design shall be used to prevent erosion at the outlet.

Source and Reference

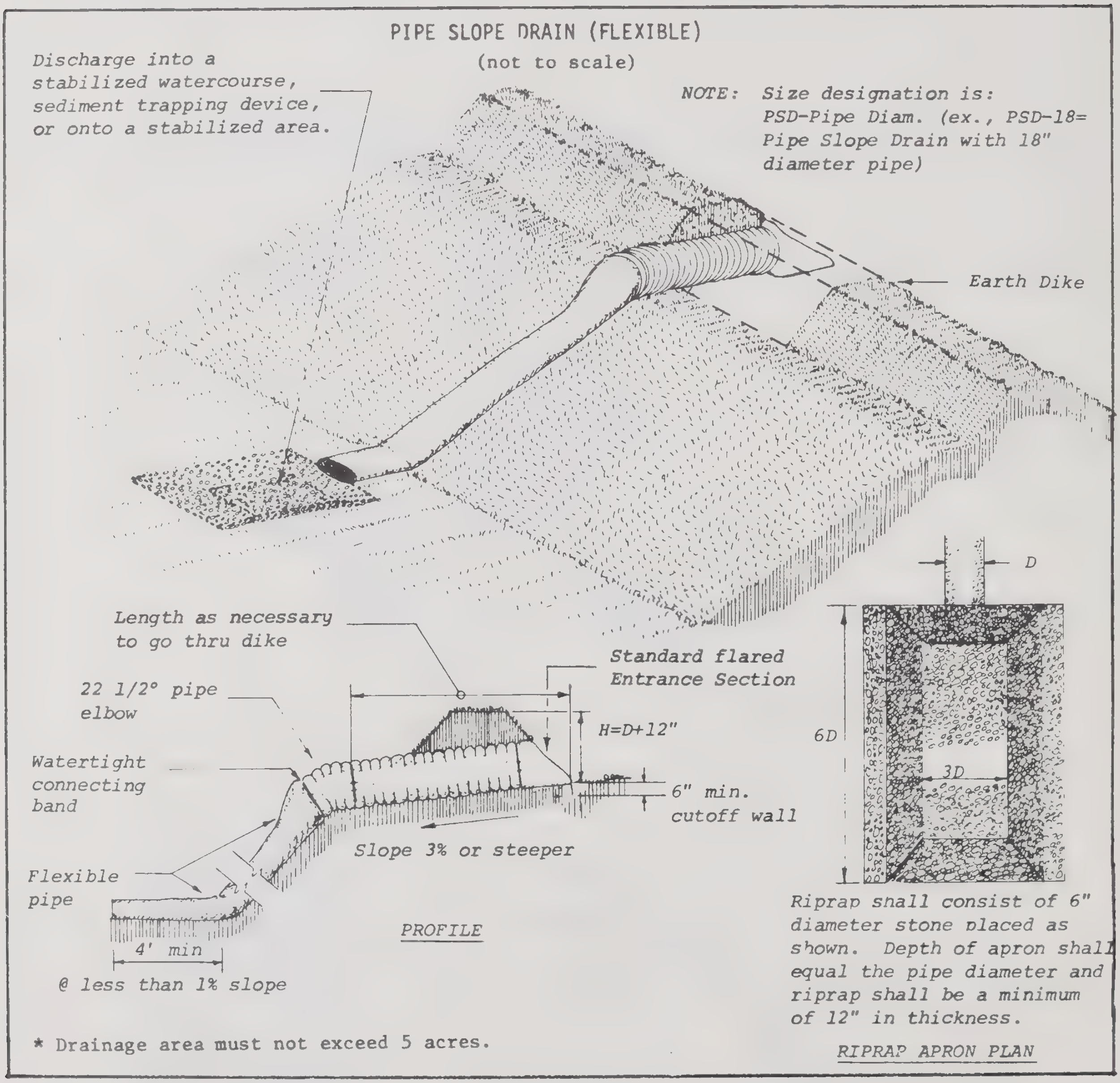
This specification was prepared from materials furnished by staff of the USDA, Soil Conservation Service and modified by ABAG for simplification and clarity.

Sample Drawing: Grade Stabilization Structure*



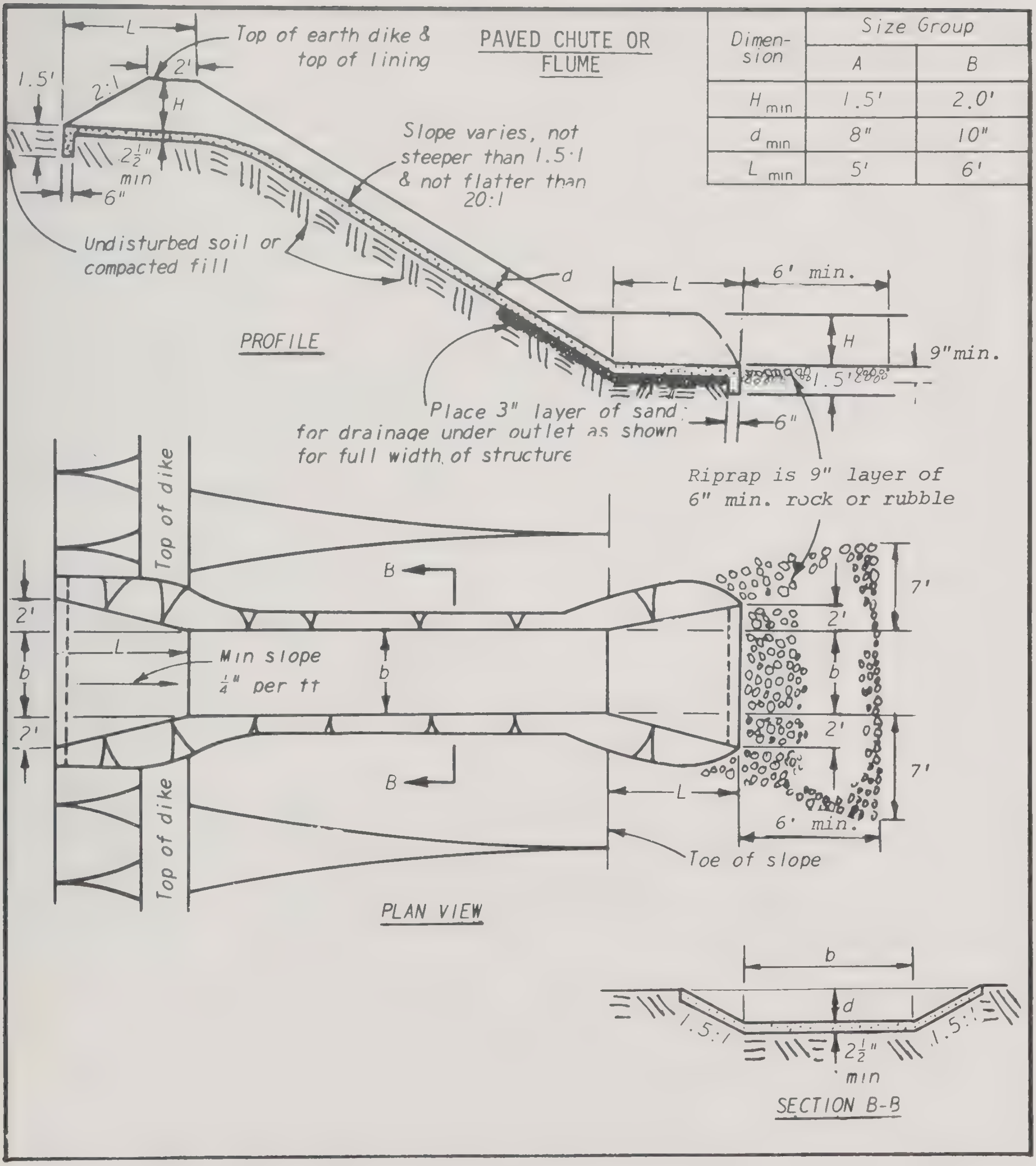
(adapted from USDA, Soil Conservation Service, College Park, Maryland. Standards and Specifications for Soil Erosion and Sediment Control in Developing Areas. July 1975.)

Sample Drawing: Grade Stabilization Structure*



(adapted from USDA, Soil Conservation Service, College Park, Maryland. Standards and Specifications for Soil Erosion and Sediment Control in Developing Areas. July 1975.)

Sample Drawing: Grade Stabilization Structure



Dimension	Size Group A	Size Group B
H_{min}	1.5'	2.0'
d_{min}	8"	10"
L_{min}	5'	6'

(adapted from USDA, Soil Conservation Service, College Park, Maryland. Standards and Specifications for Soil Erosion and Sediment Control in Developing Areas. July 1975.)

7. TEMPORARY SEDIMENT BASIN

STANDARD

Definition

A temporary basin constructed to collect and store debris or sediment.

Purpose

To collect and hold runoff to allow suspended sediment to settle out and thereby preserve the capacity of reservoirs, ditches, canals, diversions, waterways and streams; to abate or reduce pollution; to prevent undesirable deposition on bottomland and developed areas.

It is desirable to have a number of small sediment basins rather than one large basin.

Scope

This standard establishes the minimum acceptable quality standards for the design and construction of sediment basins where:

- the earthfill structure is constructed according to Earth Dams and Reservoirs, (USDA, Soil Conservation Service, Technical Release No. 60, June 1976);
- the effective height of the dam is less than 10 feet. (The effective height is the difference in elevation measured from the emergency spillway crest to the lowest point in the cross-section taken along the centerline of the dam. If there is no emergency spillway, the top of the dam is the upper limit.);
- the basin is to be removed within 12 months after the completion of construction on the site.

Conditions Where This Practice Applies

Sediment basins are constructed where physical site conditions or land ownership restrictions preclude the installation of erosion control measures to adequately control runoff, erosion and sedimentation. They are also used below construction operations that expose soil to erosion. The basin remains in place until the disturbed area is protected against erosion by permanent stabilization.

Design Considerations

Design considerations should include the following:

- o drainage area;
- o design capacity;
- o cleanout interval;
- o embankment and/or excavation specifications;
- o principal spillway;
- o emergency spillway;
- o compatibility with existing topography;
- o risk of basin failure;
- o soil erodibility, settleability and accumulation rate;
- o controlled access for safety.

It is permissable to have a number of small parallel sediment basins rather than one large basin. Small basins may be easier to locate, cheaper to build and easier to maintain. In addition, property damage risk is generally much lower with small basins.

Unit Cost Guide

$500.00-$15,000 (as of fall 1979), depending on size, local topography and site conditions.

Source and Reference

This standard was prepared from materials furnished by staff of the USDA, Soil Conservation Service and modified by ABAG for simplification and clarity.

Design Plans and Specifications

Design plans and specifications for constructing sediment basins should be in keeping with this standard and should describe the requirements for applying the practice to achieve its intended purpose. For sediment basins that exceed the limits of this standard and for alternate methods of design, consult the local USDA, Soil Conservation Service office or qualified engineers.

Plans and specifications shall comply with rules and regulations as set forth by the California Division of Safety of Dams, California Department of Fish and Game, and any other state or local agencies.

STANDARD AND SPECIFICATIONS

FOR

SEDIMENT BASIN

Definition

A temporary barrier or dam constructed across a waterway or at other suitable locations to intercept sediment-laden runoff and to trap and retain the sediment.

Scope

This standard applies to the installation of temporary sediment basins on sites where: (1) failure of the structure would not result in loss of life, damage to homes or buildings, or interruption of use or service of public roads or utilities; (2) the drainage area does not exceed 100 acres, and (3) the basin is to be removed within 36 months after the beginning of construction of the basin.

Permanent (to function more than 36 months) sediment basins, or temporary basins exceeding the classification requirements for Size 1 & 2, or structures that function as a sediment basin and later revert to a permanent pond shall be classified as permanent structures and shall conform to criteria appropriate for permanent structures. These structures shall be designed and constructed to conform to the Water Resources Law of Maryland, Title 8, Subtitle 8, (formerly Article 96A, Section 12), or SCS Engineering Memorandum MD-2 and MD SCS Standard and Specification No. 378.* The total volume of permanent sediment basins shall equal or exceed the capacity requirements for temporary basins contained herein. (10,11)

For the purpose of this standard, sediment basins are classified as follows:

Classification of Temporary Sediment Basins

Size	Max. Drainage Area, acres	Max. Height[1/] of Dam, ft.	Min. Embankment Top Width, ft.	Embankment Side Slopes	Anti-Seep Collar Req'd
1	100	10	8	2:1 or flatter	See p. 19.04
2	100	15	10	2-1/2:1 or flatter	Yes

1/ Height is measured from the low point of original ground along the centerline of dam to the top of the dam.

*In the Bay Area, structures should conform to the guidelines given under Scope in the Standard for Temporary Sediment Basin.

Purpose

The purpose of a Sediment Basin is to intercept sediment-laden runoff and reduce the amount of sediment leaving the disturbed area in order to protect drainage ways, properties, and rights-of-way below the sediment basin from sedimentation.

Conditions Where Practice Applies

A sediment basin applies where physical site conditions or land ownership restrictions preclude the installation of erosion control measures to adequately control runoff, erosion, and sedimentation. It may be used below construction operations which expose critical areas to soil erosion. It remains in effect until the disturbed area is protected against erosion by permanent stabilization.

Design Criteria For Temporary Sediment Basins

Compliance with Laws and Regulations

Design and construction shall comply with state and local laws, ordinances, rules and regulations.

Location

The sediment basin should be located to obtain the maximum storage benefit from the terrain and for ease of cleanout of the trapped sediment. It should be located to minimize interference with construction activities and construction of utilities.

Size of the Basin

The volume of the sediment basin, as measured from the bottom of the basin to the elevation of the crest of the principal spillway shall be at least 67 cubic yards per acre of total drainage area (0.5 watershed inches).(12,13)

Sediment basins shall be cleaned out when the volume as described above is reduced by sedimentation to 27 cubic yards per acre of drainage area (0.2 watershed inches), except in no case shall the sediment level be permitted to build up higher than one foot below the principal spillway crest. This cleanout shall restore the original design volume to the sediment basin. The elevation corresponding to the maximum allowable sediment level shall be determined and shall be stated in the design data as a distance below the top of riser and shall be clearly marked on the riser.

The basin dimensions necessary to obtain the required basin volume as stated above shall be clearly shown on the plans to facilitate plan review, construction and inspection.

Shape of the Basin

The basin configuration shall be such that the effective flow length is equal to at least two times the effective flow width. (i.e., The length to width ratio shall equal 2.0 or greater.) This basin shape may be attained by selecting the basin site, by excavating the basin to the required shape or by the installation of one or more baffles. See the Appendix for the detailed procedures.

Spillway Design

Runoff shall be computed by the method outlined in Chapter 2, Estimating Runoff, "Engineering Field Manual for Conservation Practices" available in the Soil Conservation Service offices, or by other methods acceptable to the local jurisdiction. Runoff computations shall be based upon the soil-cover conditions expected to prevail in the contributing drainage area during the anticipated effective life of the structure. The combined capacities of the principal and emergency spillway shall be sufficient to pass the peak rate of runoff from a ten year frequency storm. (14)

1. Principal spillway - A spillway consisting of a vertical pipe or box type riser joined (watertight connection) to a pipe (barrel) which shall extend through the embankment and outlet beyond the downstream toe of the fill. The minimum capacity of the principal spillway shall be 0.2 cfs per acre of drainage area when the water surface is at the emergency spillway crest elevation. For those basins with no emergency spillway, the principal spillway shall have the capacity to handle the peak flow from a ten year frequency rainfall event. The minimum size of the barrel shall be 8 inches in diameter. See the Appendix for principal spillway sizes and capacities.

    a. Crest elevation - When used in combination with emergency spillways, the crest elevation of the riser shall be one foot below the elevation of the control section of the emergency spillway.

    b. Watertight riser - The riser shall be completely watertight except for the inlet opening at the top or a dewatering opening and shall not have any other holes, leaks, rips or perforations in it.

    c. Dewatering the basin - There are two stages of dewatering the basin: (1) the detention pool which is below the crest of the riser and above the surface of the trapped sediment, and (2) the sediment itself which will have a high water content to the point of being "soupy".

       (1) Means for dewatering the detention pool shall be provided in all basins except those basins used with surface mining, flyash or other special operations. Means for dewatering the pool shall be included in the sediment basin plans submitted for approval and shall be installed during construction of the basin.

Dewatering shall be done in such a manner as to remove the relatively clean water without removing any of the sediment that has settled out and without removing any appreciable quantities of floating debris. Usually the detention pool may be dewatered by making a hole in the riser unless otherwise required by the approving agency. This hole shall not be larger than four inches in diameter and the lower edge of the hole shall not be lower than the required sediment cleanout elevation. For other methods of automatically dewatering the detention pool, see the Appendix.

(2) Dewatering the sediment is not required but does facilitate cleanout of the basin. The only practical means of doing this is by the use of an underdrain. Details of an acceptable underdrain system is given in the Appendix.

d. Anti-vortex device and trash rack - An anti-vortex device and trash rack shall be securely installed on top of the riser and shall be the concentric type as shown in the Appendix.

e. Base - The riser shall have a base attached with a watertight connection and shall have sufficient weight to prevent flotation of the riser. Two approved bases for risers ten feet or less in height are: (1) A concrete base 18" thick with the riser imbedded 6" in the base. (2) A 1/4" minimum thickness steel plate attached to the riser by a continuous weld around the circumference of the riser to form a watertight connection. The plate shall have 2.5 feet of stone, gravel, or tamped earth placed on it to prevent flotation. In either case, each side of the square base shall be twice the riser diameter. For risers greater than ten feet high computations shall be made to check flotation. The minimum factor of safety shall be 1.25 (Downward forces = 1.25 x upward forces).

f. Anti-seep collars - Anti-seep collars shall be installed around the pipe conduit within the normal saturation zone to increase the seepage length at least 10% when any of the following conditions exist:

(1) The settled height of dam exceeds 10 ft., or

(2) The embankment material has a low silt-clay content (Unified Soil Classes SM or GM) and the pipe diameter is 10 inches or greater.

The phreatic line may be approximated with a line drawn downward on a 4:1 slope from the intersection of the normal pool (corresponding to the top of the riser and the upstream face of the embankment.) The seepage length is the length of the flow path of a particle of water along the conduit from the riser to the point of intersection between the approximate phreatic line and

the invert of the pipe conduit. When anti-seep collars are used, the equation for revised seepage length becomes:

$$L_s + 2nV \geq 1.1\ L_s \qquad \text{or} \qquad n \geq \frac{.05L_s}{V}$$

Where: L_s = Saturated length is length, in feet, of pipe between riser and intersection of phreatic line and pipe invert.

n = number of anti-seep collars.

V = vertical projection of collar from pipe, in feet.

See the Appendix for anti-seep collar design.

The anti-seep collar and its connection to the pipe shall be watertight. The maximum spacing, in feet, between collars shall be 14 times the minimum projection of the collar measured perpendicular to the pipe. The anti-seep collar(s) shall be located below the phreatic line in the embankment and should be equally spaced. They shall not be located closer than two feet to a pipe joint. There shall be sufficient distance between collars to allow space for the hauling and compacting equipment.

g. Outlet - An outlet shall be provided including a means of conveying the discharge in an erosion-free manner to an existing stable stream. Drainage easements shall be obtained if this discharge crosses the property line before reaching the stream. These easements shall be in writing, shall be referenced on the sediment basin plan and shall be submitted for review along with the sediment basin plan. Protection against scour at the discharge end of the pipe spillway shall be provided. Measures may include impact basin, riprap, revetment, excavated plunge pools, or other approved methods. See the Standard and Specifications for Storm Drain Outlet Protection.

2. Emergency spillways - Emergency spillways shall not be constructed on fill. The emergency spillway cross-section shall be trapezoidal with a minimum bottom width of eight feet.

   a. Capacity - The minimum capacity of the emergency spillway shall be that required to pass the peak rate of runoff from the 10-year frequency storm, less any reduction due to flow in the pipe spillway. Emergency spillway dimensions may be determined by using the method in the Appendix.

   b. Velocities - The velocity of flow in the exit channel shall not exceed 6 ft. per second for vegetated channels. For channels with erosion protection other than vegetation, velocities shall be within the non-erosive range for the type of protection used.

c. Erosion protection - Erosion protection shall be provided for by vegetation as prescribed in this publication or by other suitable means such as riprap, asphalt or concrete.

d. Freeboard - Freeboard is the difference between the design high water elevation in the emergency spillway and the top of the settled embankment. If there is no emergency spillway it is the difference between the water surface elevation required to pass the design flow through the pipe and the top of the settled embankment. The freeboard shall be at least one foot.

Embankment Cross-Section

Size 1 Basins - The minimum top width shall be eight feet. The side slopes shall not be steeper than 2:1.

Size 2 Basins - The minimum top width shall be ten feet. The side slopes shall not be steeper than 2-1/2:1.

Entrance of Runoff Into Basin

Points of entrance of surface runoff into excavated sediment basins shall be protected to prevent erosion. Diversions, grade stabilization structures or other water control devices shall be installed as necessary to insure direction of runoff and protect points of entry into the basin. Points of entry should be located so as to insure maximum travel distance of entering runoff to point of exit (the riser) from the basin.

Disposal

The sediment basin plans shall indicate the method(s) of disposing of the sediment removed from the basin. The sediment shall be placed in such a manner that it will not erode from the site. The sediment shall not be deposited downstream from the basin or in or adjacent to a stream or floodplain.

The sediment basin plans shall also show the method of disposing of the sediment basin after the drainage area is stabilized, and shall include the stabilizing of the sediment basin site. Water lying over the trapped sediment shall be removed from the basin by pumping, cutting the top of the riser or other appropriate method prior to removing or breaching the embankment. Sediment shall not be allowed to flush into the stream or drainageway.

Safety

Sediment basins are attractive to children and can be very dangerous. Therefore, they shall be fenced or otherwise made inaccessible to persons or animals unless this is deemed unnecessary due to the remoteness of the site or other circumstances. In any case, local ordinances and regulations regarding health and safety must be adhered to.

CONSTRUCTION SPECIFICATIONS

Site Preparation

Areas under the embankment and any structural works shall be cleared, grubbed, and stripped of topsoil to remove trees, vegetation, roots or other objectionable material. In order to facilitate clean-out and restoration, the pool area (measured at the top of the pipe spillway) will be cleared of all brush and trees.

Cut-off Trench

A cut-off trench shall be excavated along the centerline of earth fill embankments. The minimum depth shall be two feet. The cut-off trench shall extend up both abutments to the riser crest elevation. The minimum bottom width shall be four feet, but wide enough to permit operation of excavation and compaction equipment. The side slopes shall be no steeper than 1:1. Compaction requirements shall be the same as those for the embankment. The trench shall be dewatered during the backfilling-compacting operations.

Embankment

The fill material shall be taken from approved borrow areas. It shall be clean mineral soil free of roots, woody vegetation, oversized stones, rocks, or other objectionable material. Relatively pervious materials such as sand or gravel (Unified Soil Classes GW, GP, SW & SP) shall not be placed in the embankment. Areas on which fill is to be placed shall be scarified prior to placement of fill. The fill material shall contain sufficient moisture so that it can be formed by hand into a ball without crumbling. If water can be squeezed out of the ball, it is too wet for proper compaction. Fill material shall be placed in six to eight-inch thick continuous layers over the entire length of the fill. Compaction shall be obtained by routing the hauling equipment over the fill so that the entire surface of each layer of the fill is traversed by at least one wheel or tread track of the equipment or by the use of a compactor. The embankment shall be constructed to an elevation 10% higher than the design height to allow for settlement if compaction is obtained with hauling equipment. If compactors are used for compaction, the overbuild may be reduced to not less than 5%.

Pipe Spillways

The riser shall be securely attached to the barrel by welding all around and all connections shall be watertight. The barrel and riser shall be placed on a firm smooth soil foundation. The connection between the riser and the riser base shall be watertight. Pervious materials such as sand, gravel, or crushed stone shall not be used as backfill around the pipe or anti-seep collars. The fill material around the pipe spillway shall be placed in four inch layers and compacted under the shoulders and around the pipe to at least the same density as the adjacent embankment. A minimum of two feet of hand compacted backfill shall be placed over the pipe spillway before crossing it

with construction equipment. Steel base plates shall have at least 2-1/2 feet of compacted earth, stone or gravel placed over it to prevent flotation.

Emergency Spillway

The emergency spillway shall not be installed in fill. Elevations, design width, entrance and exit channel slopes are critical to the successful operation of the emergency spillway.

Vegetative Treatment

Stabilize embankment and emergency spillway in accordance with the appropriate vegetative Standard and Specifications immediately following construction.

Erosion and Pollution Control

Construction operations shall be carried out in such a manner that erosion and water pollution will be minimized. State and local laws concerning pollution abatement shall be complied with.

Safety

State and local requirements shall be met concerning fencing and signs, warning the public of hazards of soft sediment and floodwater.

Maintenance

1. Repair all damages caused by soil erosion or construction equipment at or before end of each working day.

2. Sediment shall be removed from basin when it reaches the specified distance below the top of the riser. This sediment shall be placed in such a manner that it will not erode from the site. The sediment shall not be deposited downstream from the embankment or in or adjacent to a stream or flood plain.

Final Disposal

When temporary structures have served their intended purpose and the contributing drainage area has been properly stabilized, the embankment and resulting sediment deposits are to be leveled or otherwise disposed of in accordance with the approved sediment control plan.

INFORMATION TO BE SUBMITTED FOR APPROVAL

Sediment Basin designs and construction plans submitted for review to the Soil Conservation District, or other agency shall include the following:

A. Specific location of the dam.

B. Plan view of dam, storage basin and emergency spillway.

C. Cross section of dam, principal spillway and emergency spillway; profile of emergency spillway.

D. Details of pipe connections, riser to pipe connection, riser base, anti-seep collars, trash rack and anti-vortex device.

E. Runoff calculations for 10-year frequency storm.

F. Storage Computation

   1. Total required

   2. Total available

   3. Level of sediment at which cleanout shall be required; to be stated as a distance from the riser crest to the sediment surface.

G. Calculations showing design of pipe and emergency spillway.

Note: Items E through G above may be submitted using the design data sheet shown in the Appendix. (Appendix B)

Source and Reference

This specification was taken from the following source:

1. USDA, Soil Conservation Service, College Park, Maryland. Standards and Specifications for Soil Erosion and Sediment Control in Developing Areas. July 1975.

8. TEMPORARY SEDIMENT TRAP

STANDARD

Definition

A small temporary basin formed by excavation and/or constructing an embankment.

Purpose

To intercept sediment-laden runoff and trap the sediment, thereby protecting drainageways, properties and rights-of-way below the sediment trap from sedimentation.

Scope

This standard applies to all temporary sediment traps with a drainage area of less than 5 acres. (For traps that exceed the limits of this standard see Standard and Sample Specifications for Sediment Basins.)

Conditions Where This Practice Applies

A sediment trap is usually installed in a drainageway, at a storm drain inlet, or at other points of discharge from the disturbed area.

Design Considerations

Design considerations should include the following:

- o drainage area;
- o design capacity;
- o cleanout intervals;
- o embankment and/or excavation specifications;
- o outlet;
- o compatibility with existing topography;
- o soil erodibility, settleability and accumulation rate.

Unit Cost Guide

$500.00-$2,000.00 (as of fall 1979), depending on size, local topography and the base material.

Source and Reference

This standard was prepared from materials furnished by staff of the USDA, Soil Conservation Service and modified by ABAG for simplification and clarity.

Design Plans and Specifications

Design plans and specifications for sediment traps should be in keeping with this standard and should describe the requirements for applying the practice to achieve its intended purpose.

SAMPLE SPECIFICATIONS FOR TEMPORARY SEDIMENT TRAP

Design Specifications

1. The drainage area for a sediment trap shall be less than 5 acres.

   The sediment trap should be located to obtain the maximum storage benefit from the terrain for ease of cleanout and disposal of the trapped sediment and to minimize interference with construction activities.

2. The volume of a sediment trap as measured at the elevation of the crest of the outlet shall be at least 1,800 cubic feet per acre of drainage area. The volume of the trap shall be calculated using standard mathematical procedures. The volume of a natural basin may be approximated by the equation:

   $$V = AD$$

   V is the volume; A is the surface area; D is the maximum depth; units are feet.

3. Sediment shall be removed and the trap restored to its original dimensions when the sediment has accumulated to one-half of the design depth of the trap. Sediment removed from the trap shall be deposited in a suitable area and in such manner that it will not erode.

4. All embankments for sediment traps shall not exceed 5 feet in height as measured at the low point of the original ground along the centerline of the embankment. Embankments shall have a minimum 4-foot-wide top, and side slopes 2:1 or flatter. The embankment shall be compacted by traversing with equipment while it is being constructed. Equipment shall compact at least 90% of the surface area.

5. All excavation operations shall be carried out in such a manner that erosion and water pollution shall be minimal. Any excavated portion of the sediment trap shall have 2:1 or flatter slopes.

6. Outlets shall be designed, constructed and maintained in such a manner that settled sediment does not leave the trap and that erosion of the outlet does not occur. A trap may have several different outlets with each outlet conveying part of the flow based on the criteria below, and the combined outlet capacity shall meet these criteria. For example, a 12-foot earth outlet (adequate for 2 acres) and a 12-inch pipe outlet (adequate for 1 acre) could be used for a 3-acre drainage area.

7. If the sediment trap uses an earth outlet, the outlet width (feet) shall be equal to six times the drainage area (acres). If an embankment is used, the outlet crest shall be at least 1 foot below the top of the embankment. The outlet shall be free of any restriction to flow. (See details for earth outlet sediment trap on the sample drawing.)

8. If the sediment trap uses a pipe outlet, the outlet pipe and riser shall be made of corrugated metal. The riser diameter shall be of the same or larger diameter than the pipe. The top of the embankment shall be at least 1-1/2 feet above the crest of the riser. At least the top two-thirds of the riser shall be perforated with 1/2-inch diameter holes spaced 8 inches vertically and 10 to 12 inches horizontally. All pipe connections shall be water tight.

   Pipe diameter shall be selected from the following table:

Min. Pipe Diameter (Inches)	Max. Drainage Area (Acres)
12	1
18	2
21	3
24	4
30	5

   (Note: These pipe size specifications are examples only. The pipe dimensions for each project should be calculated by a qualified engineer based on local conditions.)

   (See details for pipe outlet sediment trap on the sample drawing.)

9. If the sediment trap uses a stone outlet, the outlet will be over a level stone section. The stone outlet for a sediment trap differs from that for a stone outlet structure because of the intentional ponding of water behind the stone. To provide for a ponding area, a relatively impervious core (e.g., timber, concrete block or straw bales) is placed in the stone. The core shall be covered by 6 inches of stone.

   The minimum length (feet) of the outlet shall be equal to six times the drainage area (acres). The crest of the outlet, at the top of the stone, shall be at least 1 foot below the top of the embankment. The crushed stone used in the outlet shall meet AASHTO M43, size No. 2 or 24, or its equivalent such as MSHA No. 2. Gravel meeting the above gradation may be used if crushed stone is not available. (See details for stone outlet sediment trap on the sample drawing.)

10. The sediment trap uses a storm inlet as its outlet. The storm drain and inlet should be placed so as not to interfere with construction activities. (See details for storm inlet sediment trap on the sample drawing.)

Construction Specifications

1. The area under embankment shall be cleared, grubbed and stripped of any vegetation and root mat. The pool area shall be cleared.

2. The fill material for the embankment shall be free of roots or other woody vegetation as well as oversized stones, rocks, organic material or other objectionable material. The embankment shall be compacted by traversing with equipment while it is being constructed.

3. Sediment shall be removed and the trap restored to its original dimensions when the sediment has accumulated to one-half of the design depth of the trap. Removed sediment shall be deposited in a suitable area and in such a manner that it will not erode.

4. The structure shall be inspected after each rain and repairs made as needed.

5. Construction operations shall be carried out in such a manner that erosion and water pollution are minimized.

6. The structure shall be removed and the area stabilized when the remaining drainage area has been properly stabilized.

7. All cut-and-fill slopes shall be 2:1 or flatter.

8. When a riser is used, all pipe joints shall be water tight.

9. When a riser is used, at least the top two-thirds of the riser shall be perforated with 1/2-inch diameter holes spaced 8 inches vertically and 10 to 12 inches horizontally.

10. When a pipe outlet is used, fill material around the pipe spillway shall be hand-compacted in 4-inch layers. A minimum of 2 feet of hand-compacted backfill shall be placed over the pipe spillway before crossing it with construction equipment.

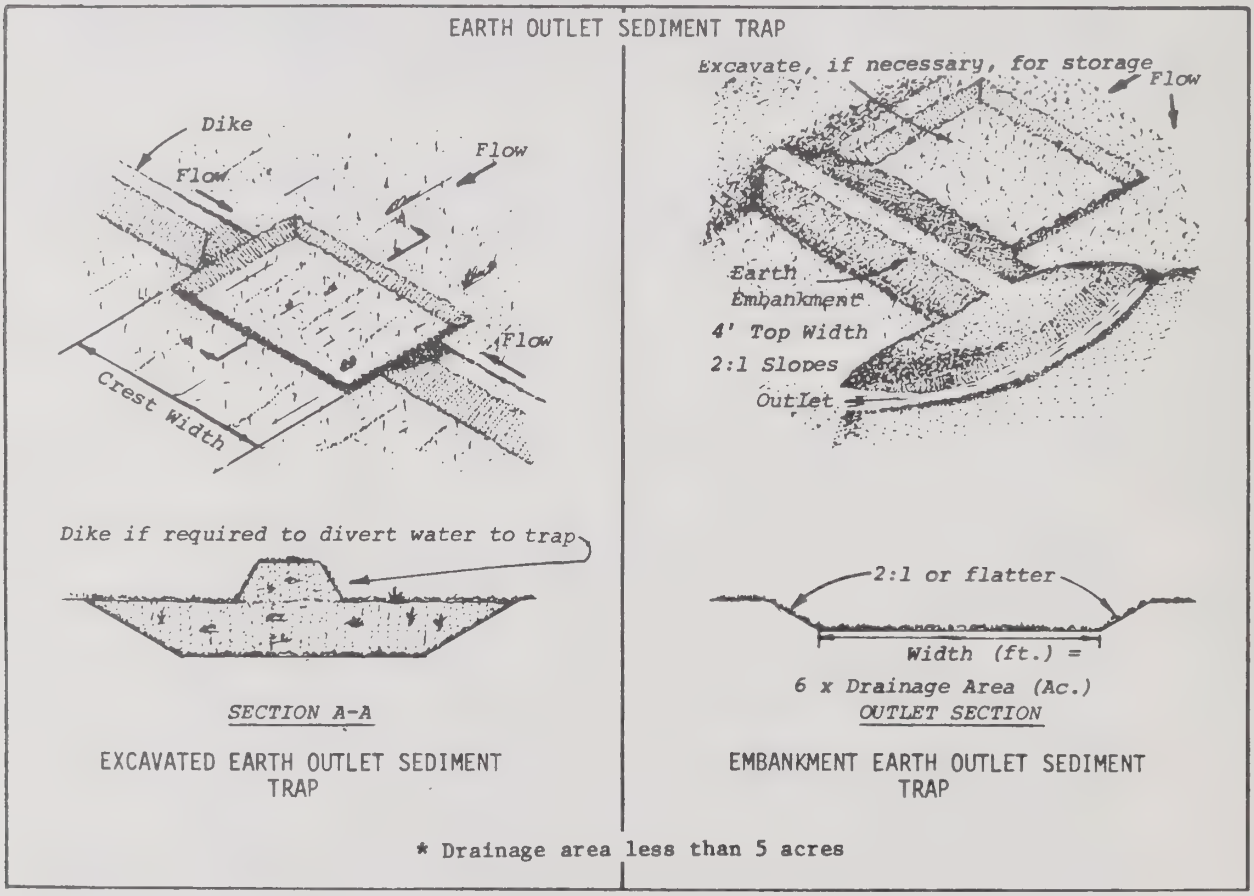
11. When an earth or stone outlet is used, outlet crest elevation shall be at least 1 foot below the top of the embankment. Pipe outlets shall be at least 1.5 feet below the top of the embankment.

12. When a crushed stone outlet is used, the crushed stone used in the outlet shall meet AASHTO designation M43 size No. 2 or 24, or its equivalent such as MSHA No. 2. Gravel meeting the above gradation may be used if crushed stone is not available. Crusher run is not acceptable.

Source and Reference

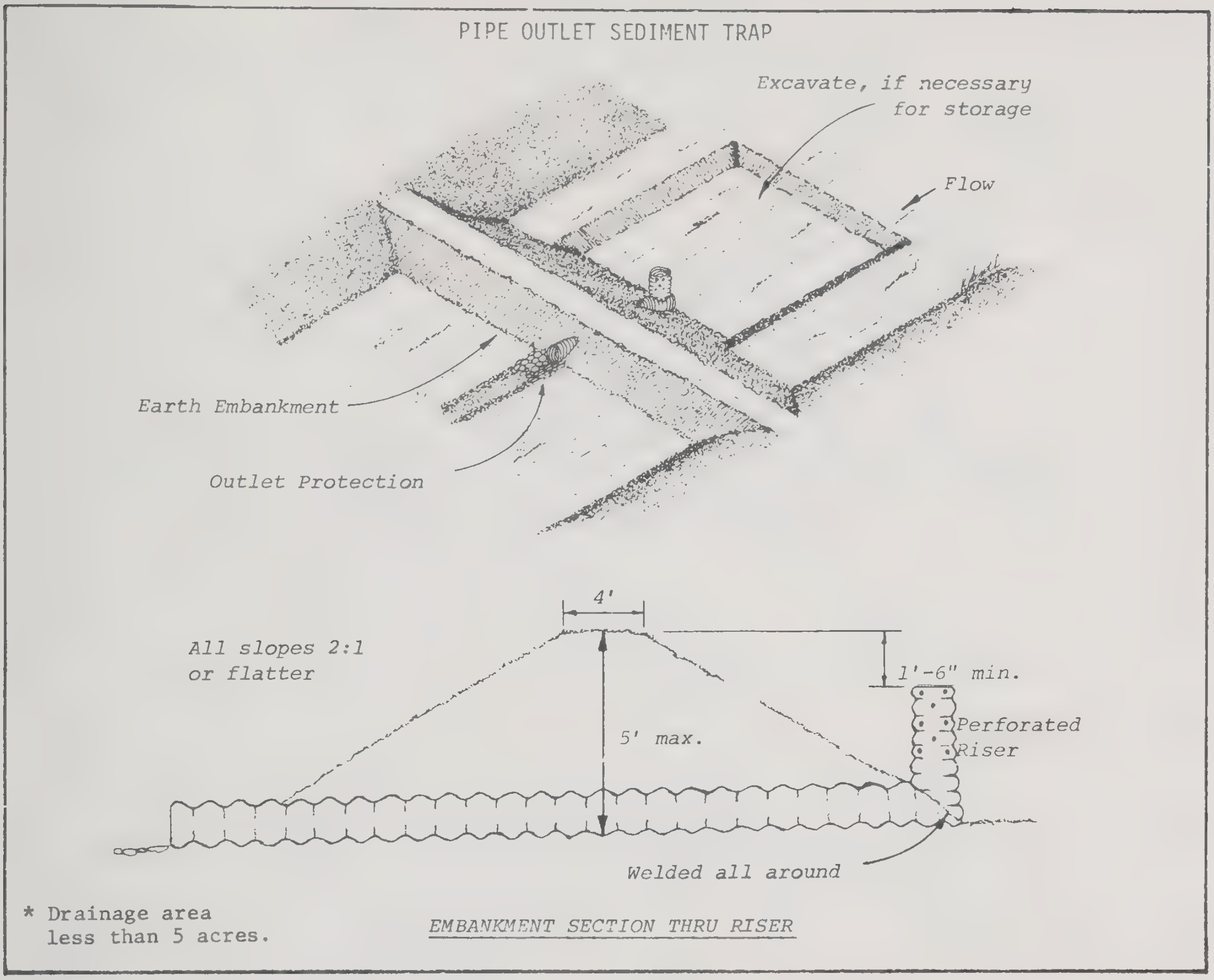
This specification was prepared from materials furnished by staff of the USDA, Soil Conservation Service and modified by ABAG for simplification and clarity.

Sample Drawing: Earth Outlet Sediment Trap*



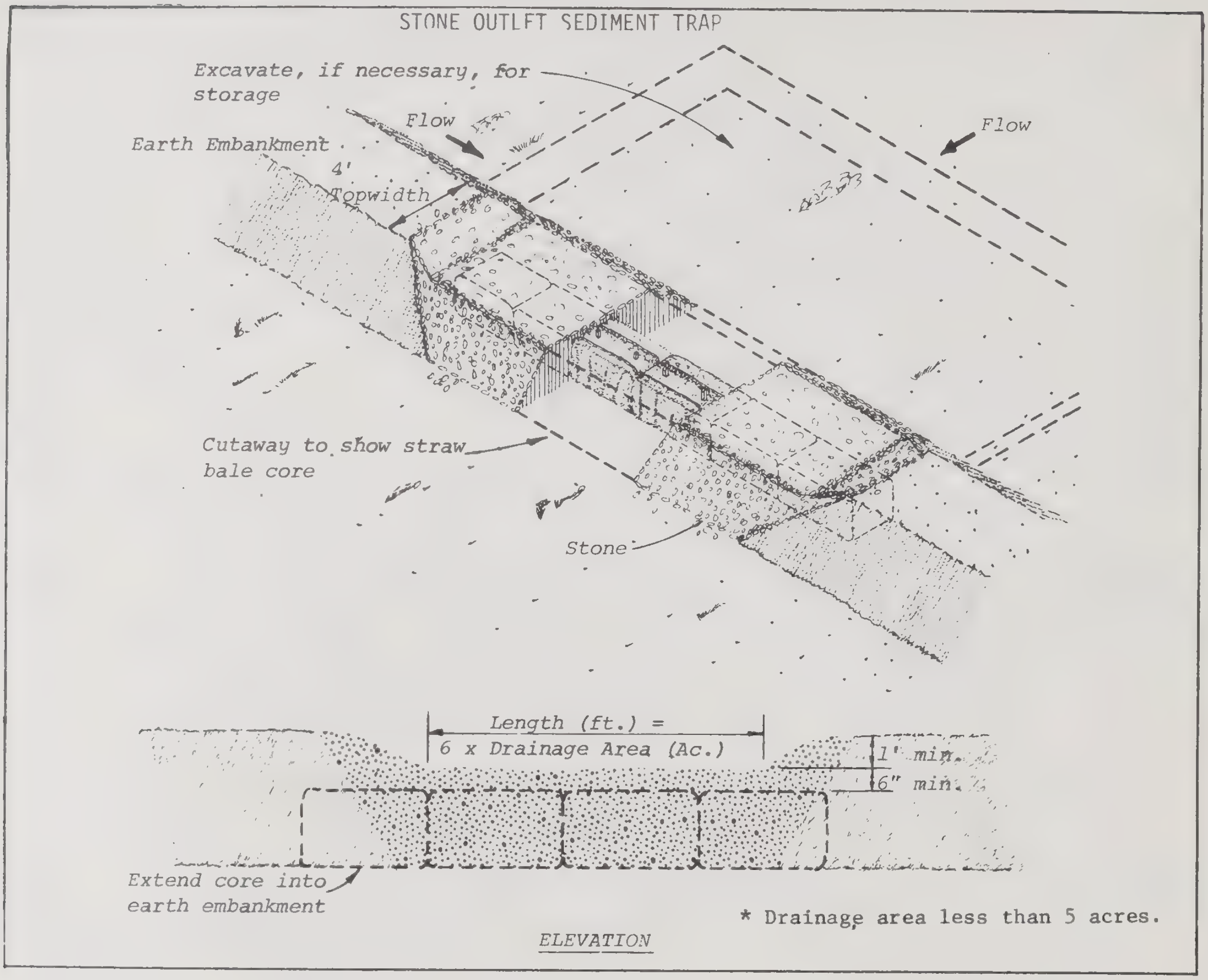
(adapted from USDA, Soil Conservation Service, College Park, Maryland. Standards and Specifications for Soil Erosion and Sediment Control in Developing Areas. July 1975.)

Sample Drawing: Pipe Outlet Sediment Trap*



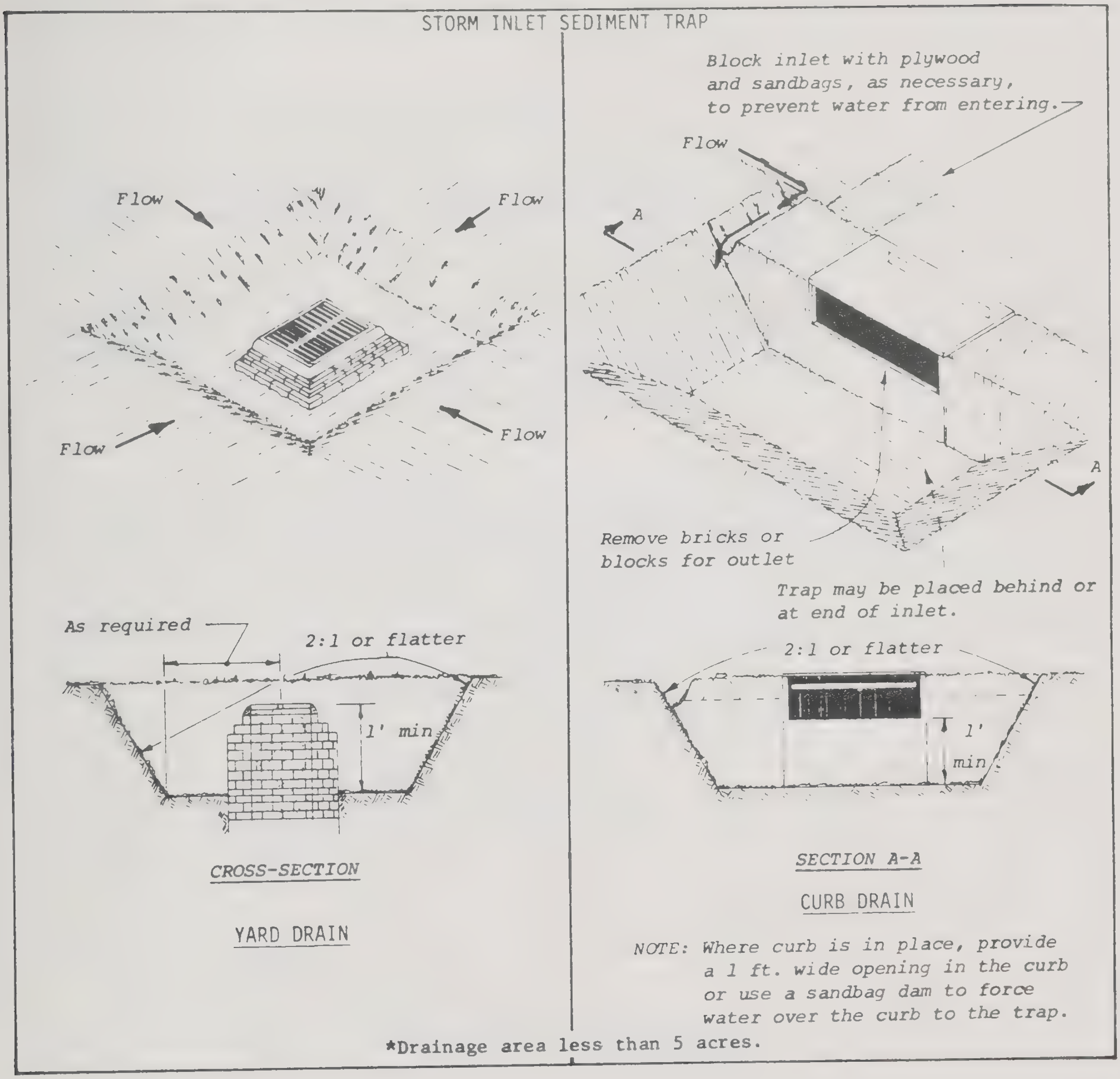
(adapted from USDA, Soil Conservation Service, College Park, Maryland. Standards and Specifications for Soil Erosion and Sediment Control in Developing Areas. July 1975.)

Sample Drawing: Stone Outlet Sediment Trap*



(adapted from USDA, Soil Conservation Service, College Park, Maryland. Standards and Specifications for Soil Erosion and Sediment Control in Developing Areas. July 1975.)

Sample Drawing: Storm Inlet Sediment Trap*



(adapted from USDA, Soil Conservation Service, College Park, Maryland. Standards and Specifications for Soil Erosion and Sediment Control in Developing Areas. July 1975.)

9. TEMPORARY STABILIZED CONSTRUCTION ENTRANCE

STANDARD

Definition

A stabilized pad of crushed stone located at any point where traffic enters or leaves a construction site at a public right-of-way, street, alley, sidewalk or parking area.

Purpose

To reduce or eliminate the tracking or flowing of sediment onto public rights-of-way.

Scope

This standard applies to all temporary stabilized construction entrances that are to be removed within 12 months after the completion of construction.

Conditions Where This Practice Applies

Stabilized construction entrances are located at all points of construction site ingress and egress.

Design Considerations

Design considerations should include the following:

- materials;
- dimensions of the pad;
- maintenance requirements.

Unit Cost Guide

$4,000-$5,000 (as of fall 1979).

Source and Reference

This standard was prepared from materials furnished by staff of the USDA, Soil Conservation Service and modified by ABAG for simplification and clarity.

Design Plans and Specifications

Design plans and specifications for stabilized construction entrances should be in keeping with this standard and should describe the requirements for applying the practice to achieve its intended purpose.

SAMPLE SPECIFICATIONS FOR TEMPORARY STABILIZED CONSTRUCTION ENTRANCE

Design and Construction Specifications

1. The material for construction of the pad shall be stone which meets AASHTO M43 size No. 2 or MSHA size No. 2.

2. The thickness of the pad shall not be less than 8 inches.

3. The width of the pad shall not be less than the full width of all points of ingress or egress.

4. The length of the pad shall be as required, but not less than 50 feet.

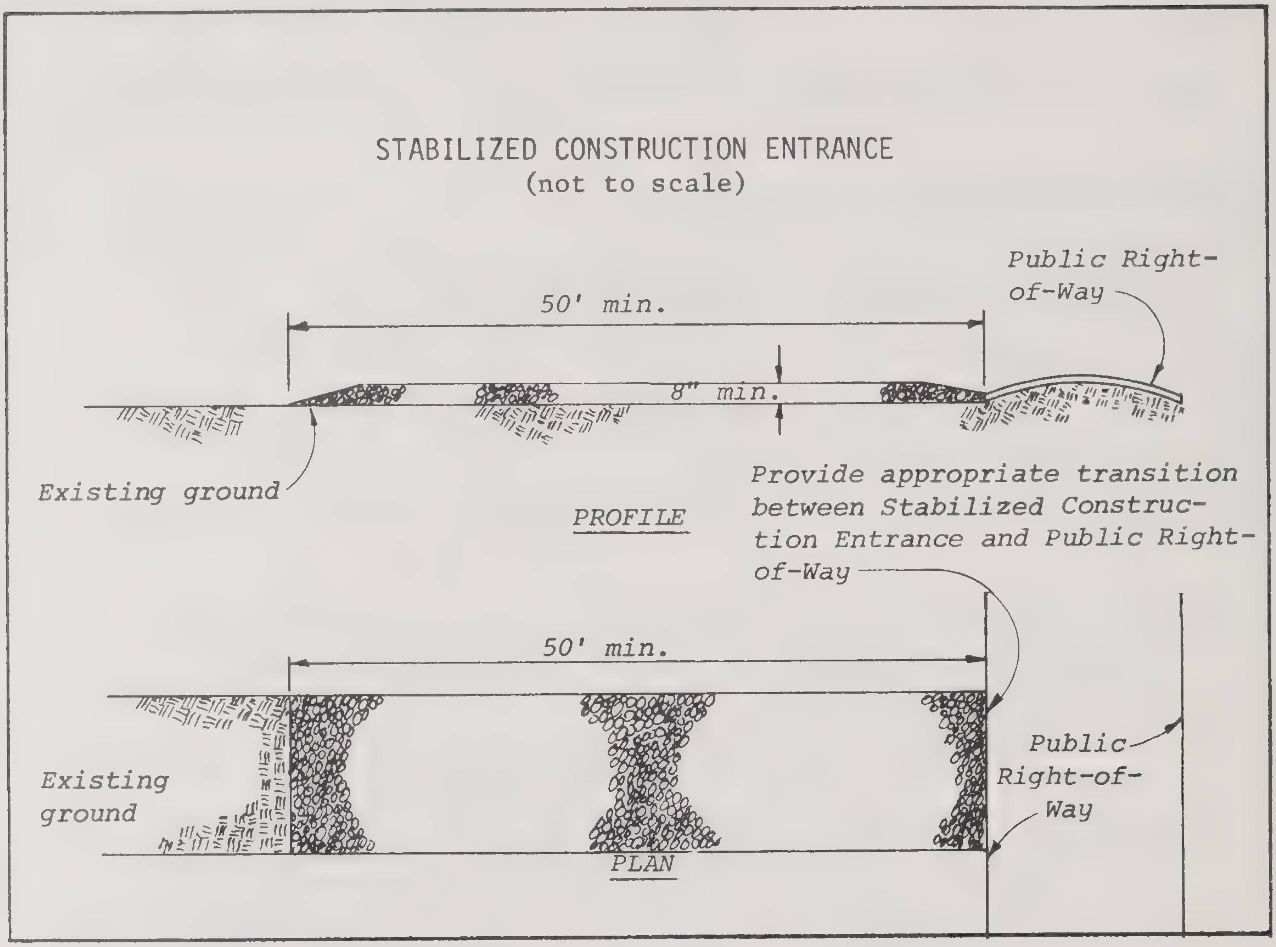
5. The entrance shall be maintained in a condition which will prevent tracking or flowing of sediment onto public rights-of-way. This may require periodic top dressing with additional stone as conditions demand and repair and/or cleanout of any measures used to trap sediment. All sediment spilled, dropped, washed or tracked onto public rights-of-way must be removed immediately.

6. When necessary, wheels must be cleaned to remove sediment prior to entrance onto public rights-of-way. When washing is required, it shall be done on an area stabilized with crushed stone which drains into an approved sediment trap or sediment basin. All sediment shall be prevented from entering any storm drain, ditch or watercourse through use of sand bags, gravel, boards or other approved methods.

Source and Reference

This specification was prepared from materials furnished by staff of the USDA, Soil Conservation Service and modified by ABAG for simplification and clarity.

Sample Drawing: Stabilized Construction Entrance



(adapted from USDA, Soil Conservation Service, College Park, Maryland. Standards and Specifications for Soil Erosion and Sediment Control in Developing Areas. July 1975.)

10. TEMPORARY STRAW BALE DIKE

STANDARD

Definition

A temporary barrier consisting of straw bales installed across or at the toe of a slope.

Purpose

To intercept and detain small amounts of sediment from limited unprotected areas.

Scope

This standard applies to all straw bale dikes that are to be removed within three months after construction.

Conditions Where This Practice Applies

The straw bale dike is used where all of the following conditions are met:

- no other practice is feasible;
- there is no concentration of water in a channel or other drainageway above the barrier;
- sheet and rill erosion would occur;
- the contributing drainage area is less than 1/2 acre and the length of slope above the dike is less than 100 feet or where a lone single-family lot has a slope on less than 15%. (The contributing drainage area in this instance shall be less than 1 acre and the length above the dike shall be less than 200 feet.)

Design Considerations

A design is not required. Bales are placed on the contour and are either wire bound or nylon string-tied and staked in place (see the sample drawing for details). The life expectancy of straw bale dikes, normally three months or less, can be extended when used with filter fabric.

Unit Cost Guide

$2.00 per linear foot (as of fall 1979).

Source and Reference

This standard was prepared from materials furnished by staff of the USDA, Soil Conservation Service and modified by ABAG for simplification and clarity.

Design Plans and Specifications

Design plans and specifications for straw bale dikes should be in keeping with this standard and should describe the requirements for applying the practice to achieve its intended purpose.

SAMPLE SPECIFICATIONS FOR TEMPORARY STRAW BALE DIKE

Construction Specifications

1. Bales shall be placed in a row with ends tightly abutting the adjacent bales.

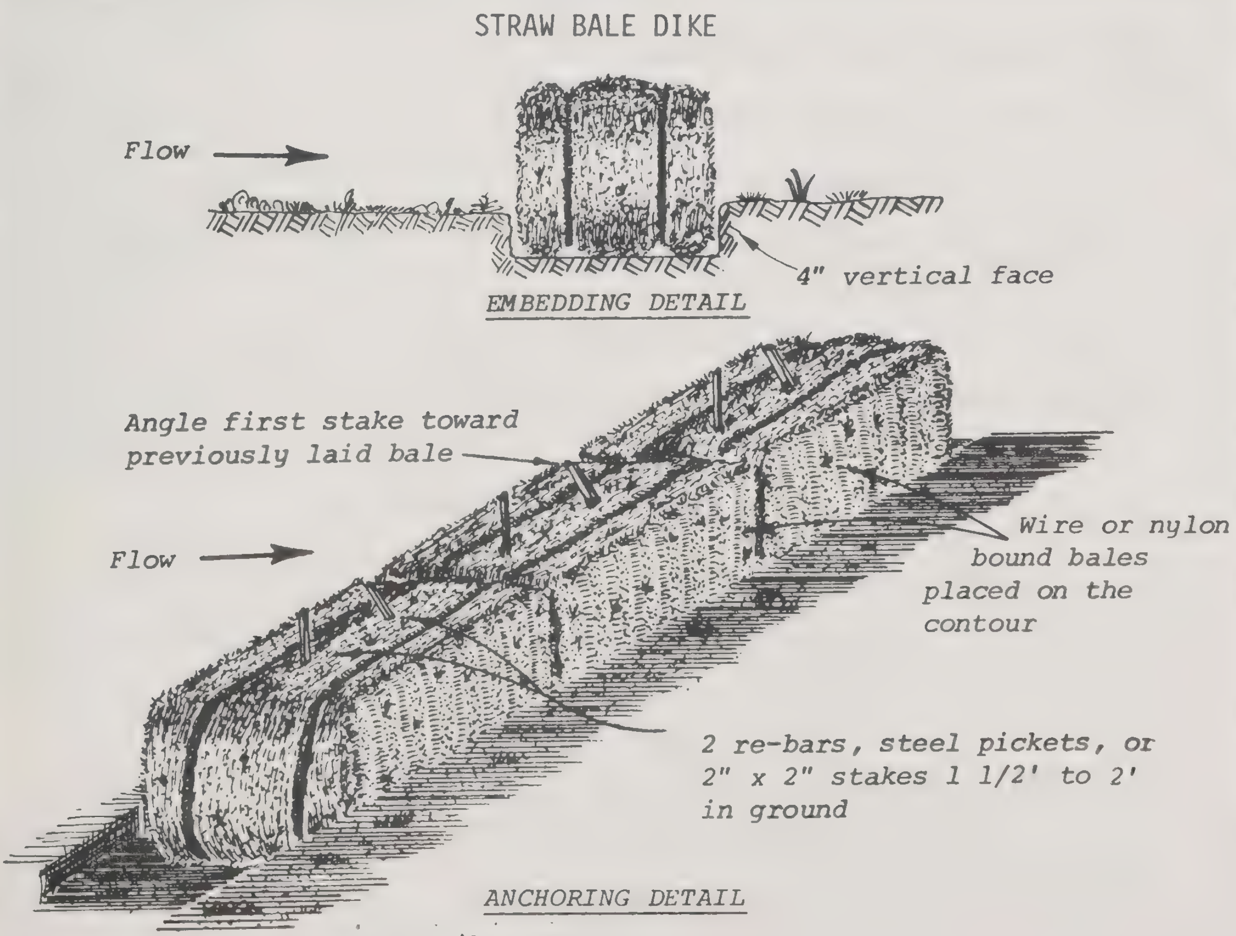
2. Each bale shall be embedded in the soil a minimum of 4 inches.

3. Bales shall be securely anchored in place by stakes or re-bars driven through the bales. The first stake in each bale shall be driven toward the previously-laid bale to force bales together.

4. Inspection shall be after each storm, and repair or replacement shall be made promptly as needed.

5. Bales shall be removed when they have served their usefulness so as not to block or impede storm flow or drainage.

Sample Drawing: Straw Bale Dike*



* Drainage area less than 1/2 acre.

(adapted from USDA, Soil Conservation Service, College Park, Maryland. Standards and Specifications for Soil Erosion and Sediment Control in Developing Areas. July 1975.)

11. TEMPORARY SILT FENCE

STANDARD

Definition

A temporary barrier, consisting of posts, wire mesh and filter cloth, installed below small disturbed areas or at the toe of a slope.

Purpose

The purpose of a silt fence is to intercept and detain sediment from small disturbed or unprotected areas.

Scope

This standard applies to all silt fences that are to be removed when construction activities are completed.

Conditions Where This Practice Applies

A silt fence may be used where:

- o no other practice other than straw bale dike is feasible;
- o there is no concentration of water in a channel or other drainage way above the barrier;
- o erosion will occur in the form of sheet and rill erosion;
- o protection of adjacent property or area beyond the limits of grading is needed;
- o contributing drainage area is less than 1/2 acre.

Design Considerations

Design computations are not required. Silt fences should be placed as close to the contour as possible.

Design considerations should include the following:

- o type, size, and spacing of fence posts;
- o size of woven wire support fence;
- o type of filter cloth used;
- o method of anchoring the filter cloth.

The life expectancy of a silt fence is normally one season.

Unit Cost Guide

$4.00-$6.00 per linear foot (as of fall 1979).

Sources and References

This standard was prepared by ABAG based on the following sources:

1. Sherwood, W. Cullen and David C. Wyant. Installation of Straw and Fabric Filter Barriers for Sediment Control (a paper prepared for the Annual Meeting of the Transportation Research Board, Washington, D.C.). January 1979.

2. U.S. Department of Agriculture, Soil Conservation Service, Maryland.

3. Abel, Phillip E., Landscape Architect. Martinez, California.

Design Plans and Specifications

Design plans and specifications for silt fences should be in keeping with this standard and should describe the requirements for applying the practice to achieve its intended purpose.

SAMPLE SPECIFICATIONS FOR TEMPORARY SILT FENCE

Materials

1. Silt Fence Cloth: Material shall meet ASTM Standard Coefficient of Permeability 4 x 10 centimeters per second. Material shall be ultra-violet resistant.

2. Fence Posts: The length shall be a minimum of 60 inches long. Wood posts shall be of sound quality with a minimum diameter of 2 inches or as approved. Steel posts shall be standard T section or round and weigh not less than 1.33 pounds per linear foot. Substitution of an equivalent fence post specification is allowed subject to approval of a qualified engineer.

3. Wire Fence: Woven wire fencing shall be a minimum 14-1/2 gage with a maximum 6-inch mesh opening, or as approved.

Construction Specifications

1. The fence posts shall be spaced a maximum distance of 10 feet center-to-center.

2. Woven wire fence shall be fastened securely to the upstream side of the fence posts by staples or wire ties.

3. A trench at least 6 inches deep shall be excavated on the upstream side of the fence.

4. The filter cloth shall be stapled or securely fastened to the upstream side of the woven wire. Sufficient filter cloth shall be allowed to extend to the bottom of the trench and back up to the upstream side of trench (as shown in the sample drawing).

5. The trench shall be backfilled with soil and compacted to the original ground level.

6. The fence shall be inspected during each storm and the filter cloth shall be replaced promptly as needed if it is torn.

7. Silt shall be removed periodically to keep the silt level from reaching halfway to the top of the fence.

Sources and References

This specification was prepared by ABAG based on the following sources:

1. Sherwood, W. Cullen and David C. Wyant. Installation of Straw and Fabric Filter Barriers for Sediment Control (a paper prepared for the Annual Meeting of the Transportation Research Board, Washington, D.C.). January 1979.

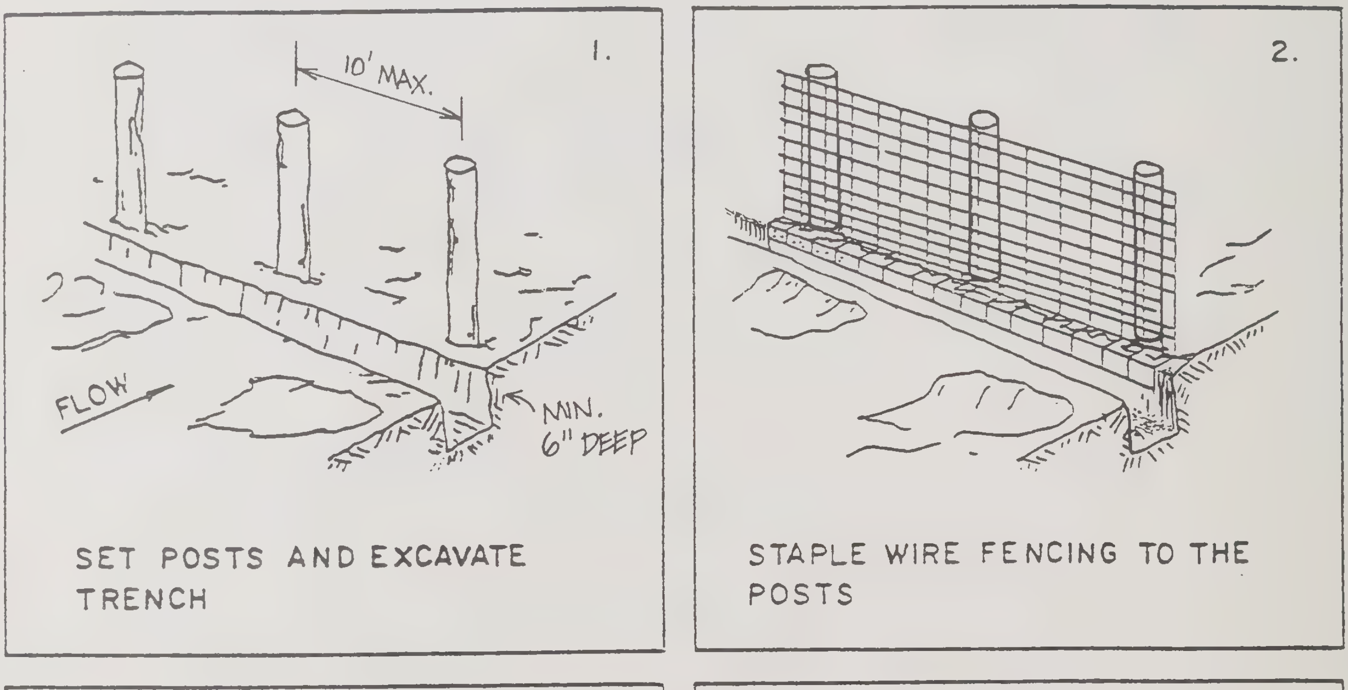
2. U.S. Department of Agriculture, Soil Conservation Service, Maryland.

3. Abel, Phillip E., Landscape Architect. Martinez, California.

Sample Drawing: Silt Fence

BUILDING A SILT FENCE

A STEP BY STEP PROCEDURE



(adapted from USDA, Soil Conservation Service, College Park, Maryland. Standards and Specifications for Soil Erosion and Sediment Control in Developing Areas. July 1975.)

12. PERMANENT GRASSED WATERWAY

STANDARD

Definition

A natural or constructed waterway or outlet, shaped or graded and lined with suitable vegetation.

Purpose

To transport excess surface water from terraces, diversions, subdivisions or natural drainage areas without causing erosion or flooding.

Scope

This standard applies to natural or constructed channels that are to be lined with vegetation and used for water conveyance in a wide and shallow flow.

Conditions Where This Practice Applies

Permanent grassed waterways are used on sites where added capacity, vegetative protection, or both, are required to control erosion resulting from concentrated runoff and where such control can be achieved by the use of these practices alone or in combination with others.

Design Considerations

Design considerations should include the following:

- o capacity;
- o allowable water velocity;
- o width;
- o depth;
- o drainage;
- o outlets;
- o maintenance requirements;
- o access control for public safety.

Unit Cost Guide

Grass establishment: $1.00-$1.50 per square foot (as of fall 1979).

Source and Reference

This standard was prepared from materials furnished by staff of the USDA, Soil Conservation Service and modified by ABAG for simplification and clarity.

Design Plans and Specifications

Design plans and specifications for grassed waterways or outlets should be in keeping with this standard and should describe the requirements for applying the practice to achieve its intended purpose.

SAMPLE SPECIFICATIONS FOR PERMANENT GRASSED WATERWAY

Design Specifications

1. The minimum capacity shall be that required to confine the peak rate of runoff expected from a 25-year-frequency rainfall event, or a higher frequency, corresponding to the hazard involved. This requirement for confinement is waived on slopes of less than 1% where out-of-bank flow will not cause erosion or property damage.

   Peak rates of runoff values used in determining the capacity requirements shall be as outlined in "Estimating Runoff" (Chapter 2 of Engineering Field Manual for Conservation Practices, USDA, Soil Conservation Service), or by other accepted methods.

   Where there is base flow (winter), it shall be handled by a stone center, subsurface drain or other suitable means since sustained wetness usually prevents adequate vegetative cover. The cross-sectional area of the stone center or subsurface drain to be provided shall be determined by using a flow rate of 0.1 cfs per acre or by actual measurement of the maximum base flow.

2. Maximum permissible velocities of flow for the stated conditions of stabilization are shown below:

Cover	Range of Channel Gradient (Percent)	Permissible Velocity (Feet per Second)
Vegetative 1/		
Tufcote, Tifway, Santa Anna or Coastal Bermudagrass	0 to 5.0	6
	5.1 to 10.0	5
	over 10.0	4
Alta or Goar tall fescue	0 to 5.0	5
	5.0 to 10.0	4
	over 10.0	3
Annuals 2/		
Small grain (rye, oats, barley, millet) Ryegrass	0 to 5.0	2.5
Vegetative with stone center for base flow		As determined for the vegetative portion as shown above.

1/ To be used only below stabilized or protected areas.
2/ Annuals to be used as temporary protection only until permanent vegetation is established.

3. The design water surface elevation of a waterway receiving water from diversions or other tributary channels shall be equal to or less than the design water surface elevation in the diversion or other tributary channels.

   The top width of parabolic waterways shall not exceed 30 feet, and the bottom width of trapezoidal waterways shall not exceed 15 feet unless multiple or divided waterways, stone center or other means are provided to control meandering of low flows.

   The design procedures for parabolic and trapezoidal channels are given in Appendix C. (See sample drawings for details.)

4. Each waterway shall have a stable outlet. The outlet may be another waterway, a stabilized open channel, grade stabilization structure, etc. In all cases, the outlet must discharge in such a manner as not to cause erosion. Outlets shall be constructed and stabilized prior to the operation of the waterway.

5. Subsurface drainage measures shall be provided for sites having high water tables or seepage problems, except where water-tolerant vegetation can be used.

   Where there is base flow, a stone center, a subsurface drain or other suitable means shall be required.

6. An adequate irrigation system shall be provided to insure the success of the grassed waterway.

7. Waterways shall be stabilized. For recommendations on seedbed preparation, seeding, fertilizing and mulching, consult the local office of the Soil Conservation Service.

<u>Construction Specifications</u>

1. All trees, brush, stumps, obstructions and other objectionable material shall be removed and disposed of so as not to interfere with the proper functioning of the waterway.

2. The waterway shall be excavated or shaped to line, grade and cross-section as required to meet the criteria specified herein, and be free of bank projections or other irregularities which will impede normal flow.

3. Fills shall be compacted as needed to prevent unequal settlement that would cause damage to the completed waterway.

4. All earth removed and not needed in construction shall be spread or disposed of so that it will not interfere with the function of the waterway.

5. Stabilization shall be done as follows:

   (a) For design velocities of less than 3.5 feet per second, seeding and mulching may be used for the establishment of the vegetation. It is recommended that, when conditions permit, temporary diversions or other means should be used to prevent water from entering the waterway during the establishment of the vegetation.

   (b) For design velocities of more than 3.5 feet per second, the waterway shall be stabilized with sod, with seeding protected by jute or excelsior matting, or with seeding and mulches, including temporary diversion of the water until the vegetation is established. (See Appendix A, Standards and Specifications for Protective Materials for Channels and Steep Slopes.)

6. Structural protection shall be according to the following:

   (a) Stone centers for base flow shall be constructed as shown in the sample drawing.

       The stone center portion shall be stabilized with riprap according to the Standard and Sample Specifications for Riprap.

   (b) A subsurface drain for the base flow shall be constructed as shown on the sample drawing and as specified in the Standard and Sample Specifications for Subsurface Drain.

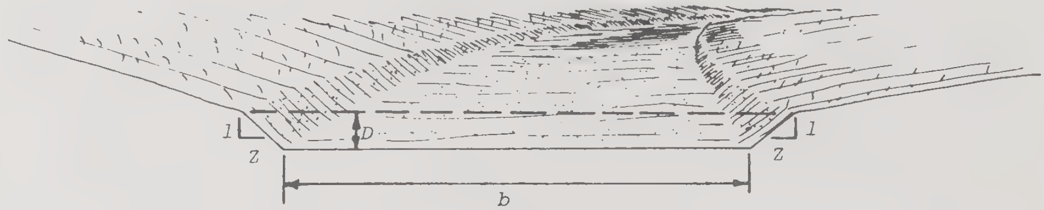
   (c) Gabion mattress channel liners may be used for base flow, design flow and subsurface drainage.

<u>Source and Reference</u>

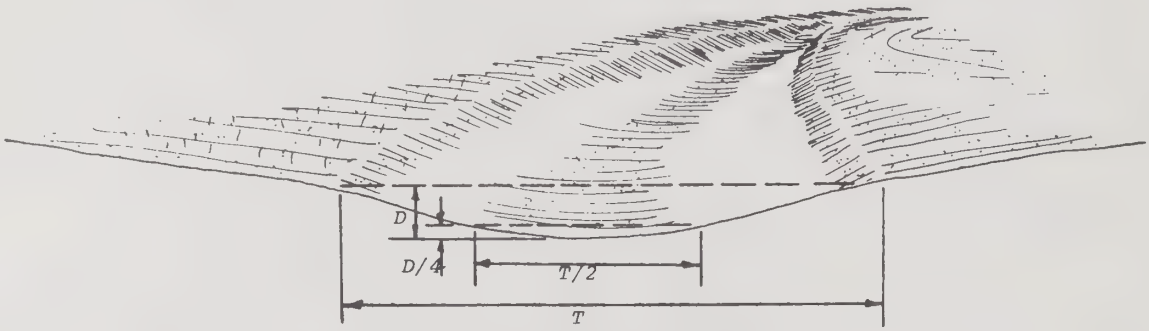
This specification was prepared from materials furnished by staff of the USDA, Soil Conservation Service and modified by ABAG for simplification and clarity.

Sample Drawing: Grassed Waterway

GRASSED WATERWAY



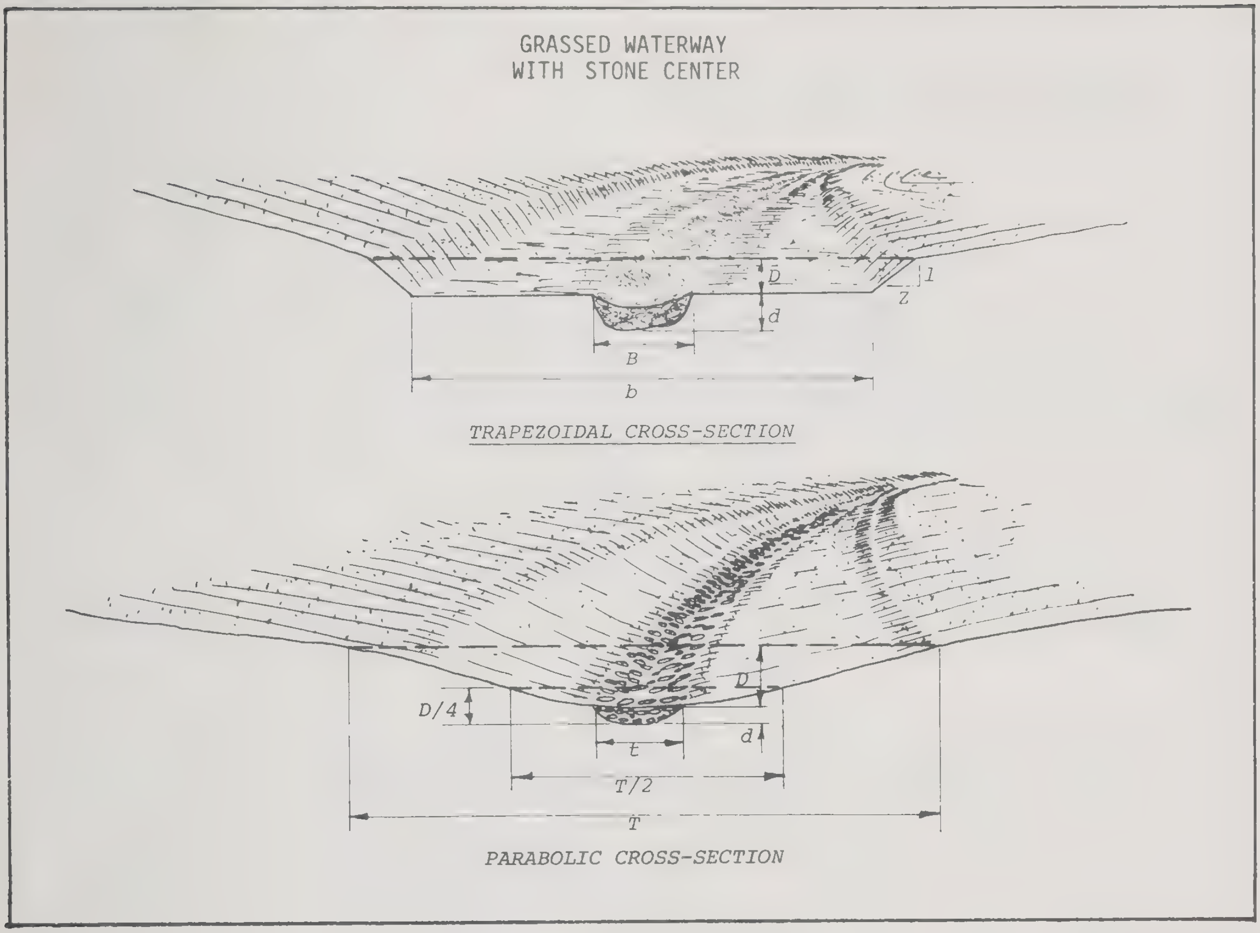
TRAPEZOIDAL CROSS-SECTION



PARABOLIC CROSS-SECTION

(adapted from USDA, Soil Conservation Service, College Park, Maryland. Standards and Specifications for Soil Erosion and Sediment Control in Developing Areas. July 1975.)

Sample Drawing: Grassed Waterway With Stone Center



(adapted from USDA, Soil Conservation Service, College Park, Maryland. Standards and Specifications for Soil Erosion and Sediment Control in Developing Areas. July 1975.)

13. PERMANENT LINED WATERWAY OR OUTLET

STANDARD

Definition

A waterway or outlet having an erosion-resistant lining of concrete, stone or other permanent material extending up the side slopes to a designed depth. (Earth above the permanent lining may be vegetated or otherwise protected.)

Purpose

To provide for conveyance of runoff from other erosion or sediment control structures or from natural concentrations of flow, without damage by erosion or flooding; to control seepage, piping, and sloughing or slides.

Scope

This standard applies to waterways or outlets having linings of nonreinforced, cast-in-place concrete; flagstone mortared in place; rock riprap; or similar permanent materials. It does not apply to irrigation water conveyances or to grassed waterways with stone centers or short lined sections. The maximum capacity of the waterway flowing at designed depth shall not exceed 200 cfs.

Conditions Where This Practice Applies

Permanent lined waterways or outlets are used where any of the following or similar conditions exist:

- o concentrated runoff is such that a lining is needed to control erosion;
- o steep grades, wetness, prolonged base flow, seepage or piping would cause erosion;
- o the location is such that use by people or animals preclude use of vegetated waterways or outlets;
- o high-value property or adjacent facilities warrant the extra cost to contain design runoff in a limited space;
- o soils are highly erodible or other soil or climatic conditions preclude using unlined or grassed waterways.

Design Considerations

Design considerations should include the following:

- o water velocity;
- o cross section;
- o freeboard;
- o side slope;
- o lining thickness;
- o related structures;
- o filters or bedding;
- o materials (concrete or mortar, riprap or flagstone);
- o contraction joints;
- o maintenance requirements.

Nonreinforced concrete or mortared flagstone linings should be installed only on low shrink-swell soils that are well drained or where subgrade drainage facilities are installed.

Unit Cost Guide

Concrete: $100.00-$200.00 per cubic yard (as of fall of 1979), depending on type needed.

Source and Reference

This standard was prepared from materials furnished by staff of the USDA, Soil Conservation Service and modified by ABAG for simplification and clarity.

Design Plans and Specifications

Design plans and specifications for constructing lined waterways or outlets should be in keeping with this standard and should describe the requirements for applying the practice to achieve its intended purposes.

SAMPLE SPECIFICATIONS FOR PERMANENT LINED WATERWAY OR OUTLET

Sample specifications for permanent lined waterway or outlet are not yet available for the Bay Area. They will be contained in a future edition of this manual. In the interim, contact the local office of the Soil Conservation Service or a qualified engineer.

14. PERMANENT RIPRAP

STANDARD

Definition

A layer of loose rock or aggregate placed over an erodible soil surface.

Purpose

To protect the soil surface from the erosive forces of water.

Scope

This standard applies to the design and placement of all nongrouted riprap where the slopes are 2:1 or flatter. (For design and placement of grouted riprap on slopes steeper than 2:1, consult the local USDA, Soil Conservation Service office or other qualified engineers.)

Conditions Where This Practice Applies

Permanent riprap is used on storm drain outlets, channel banks and bottoms, roadside ditches, drop structures, shorelines and any other outlet where soil conditions, water turbulence and velocity, expected vegetative cover and groundwater conditions are such that the soil may erode under the design flow conditions.

Design Considerations

Design considerations should include the following:

- peak discharge from a 10-year-frequency storm that the riprap will be expected to carry;
- erosive forces of flowing water;
- slope and placement;
- size and quality of material;
- placement and quality of bedding;
- maintenance requirements.

Unit Cost Guide

$5.50-$9.00 per cubic yard (as of fall 1979), depending on size of riprap and distance from quarry.

Source and Reference

This standard was prepared from materials furnished by staff of the USDA, Soil Conservation Service and modified by ABAG for simplification and clarity.

Design Plans and Specification

Design plans and specifications for riprap should be in keeping with this standard and should describe the requirements for applying the practice to achieve its intended purpose.

SAMPLE SPECIFICATIONS FOR PERMANENT RIPRAP

Design Specifications

1. The minimum design discharge for channels and ditches shall be the peak discharge from a 10-year-frequency rainfall based on maximum watershed development during the life of the structure. The roughness coefficient "n", used for determining flow on the constructed riprap surface, shall be as given by curve 1 in Appendix D.

   For design of riprap-lined channels, refer to Tentative Design Procedure for Riprap Lined Channels (National Cooperative Highway Research Program Report Number 108). This is a procedure for determining a design stone size such that the stone is stable under the design flow conditions with a reasonable factor of safety. The design stone size used in this standard and specifications is the d50 or median stone diameter, which is defined as the stone size such that 50% of the mixture, by weight, is larger than that size. The riprap design procedure is given in Appendix D.

   Erosive forces of flowing water are greater in bends than in straight channels. Riprap size for bends in the channel shall be computed according to the procedure in Appendix D. If the riprap size (d50) computed for bends is less than 10% greater than the riprap size (d50) for straight channels, then the riprap size for straight channels shall be considered to be adequate size; otherwise the larger riprap size shall be used in the bend. This allowance is made in order to minimize the number of riprap sizes required. No more than two riprap sizes should be used on any single contract in order to minimize construction problems caused by too many sizes. The riprap size to be used in a bend shall extend upstream from the point of curvature and downstream from the point of tangency a distance equal to five times the channel bottom width (length = 5b). This riprap size shall extend across the bottom and up both sides of the channel.

   For erosion of tidal shores, see Shore Protection Manual (U.S. Army Corps of Engineers).

2. The riprap shall be composed of a well-graded mixture down to the 1-inch size particle such that 50% of the mixture by weight shall be larger than the d50 size as determined from the design procedure. A well-graded mixture as used herein is defined as a mixture composed primarily of the larger stone sizes but with a sufficient mixture of other sizes to fill the progressively smaller voids between the stones. The diameter of the largest stone size in such a mixture shall be considered to be 1.5 times the d50 size.

The riprap size as shown on the plans and specifications or for other construction purposes shall be the size of the largest stone in the mixture, i.e., 1.5 x d50. The minimum thickness of the riprap layer shall be 1.5 times the maximum stone diameter, but not less than 6 inches. The riprap shall extend up the banks to a height equal to the maximum depth of flow or to a point where vegetation can be established to adequately protect the channel.

In channels where there is no riprap or paving in the bottom, the toe of the bank riprap shall extend below the channel bottom a distance at least 1.5 times the maximum stone size, but in no case less than 1 foot. The only exception to this would be in the event that there is a nonerodible hard-rock bottom. The channel bank shall not be steeper than 2:1.

The designer, after determining the riprap size that will be stable under the flow conditions, shall consider that size to be a minimum size and then, based on riprap gradations actually available in the area, shall select the size or sizes that equal or exceed the minimum size. The possibility of damage by children shall be considered in selecting a riprap size, especially if there is nearby water into which the stones may be tossed.

3. Stone for riprap shall consist of field stone or rough unhewn quarry stone of approximately rectangular shape. The stone shall be hard and angular and of such quality that it will not disintegrate on exposure to water or weathering, and it shall be suitable in all other respects for the purpose intended. The specific gravity of the individual stones shall be at least 2.5.

   Rubble concrete may be used provided it has a density of at least 150 pounds per cubic foot and otherwise meets the requirements of this standard and specifications.

4. Riprap shall have a filter placed under it when either of the following conditions exist:

   (a) The riprap is not well-graded down to the 1-inch size particle.

   (b) Riprap is placed on the side slopes of a channel, and the soil is sand-size or finer with a plasticity index of less than 10. This requirement applies to slopes having this soil in lenses or layers greater than 3 inches in thickness.

   A filter can be of two general forms. One is a single layer of plastic filter cloth manufactured for that express purpose. The plastic filter cloth shall be woven of polypropylene monofilament yarns and shall be equivalent to Poly-Filter X as manufactured by Carthage Mills, Inc., Cincinnati, Ohio. Another is a properly-graded layer of sand, gravel or stone.

The criteria for the design of an aggregate filter is as follows:

$$\frac{d\ 15\ \text{Riprap}}{d\ 85\ \text{Filter}} \leq 5 \qquad \frac{d\ 15\ \text{Filter}}{d\ 85\ \text{Base}} \leq 5$$

in which d15 and d85 are the sizes of base, filter or riprap material, of which 15% and 85% respectively is finer. The base means the soil layer underneath the filter. The filter shall be graded down to sand-size particles. Riprap that is 12 inches and larger shall not be dumped directly onto the plastic filter cloth, as it may tear or displace the filter cloth. Instead, a 4-inch-thick (minimum) blanket of gravel shall be placed over the filter cloth, or the riprap shall be placed directly on the filter cloth by hand or by the bucket of the equipment. Side slopes shall be 2:1 or flatter in order for the gravel not to slide down the filter cloth before the riprap is put in place.

5. Soil sizes given herein are according to the Unified Soil Classification System as shown below.

Soil	Sieve Size
Gravel	Smaller than 3 inches and larger than No. 4 sieve (approx. 1/4 inch)
Sand	Smaller than No. 4 sieve and larger than No. 200 sieve (0.074 millimeter)

Construction Specifications

1. The subgrade for the riprap or filter shall be prepared to the required lines and grades. Any fill required in the subgrade shall be compacted to a density approximating that of the surrounding undisturbed material.

2. The rock or gravel shall conform to the specified grading limits when installed respectively in the riprap or filter.

3. Plastic filter cloth shall be protected from punching, cutting or tearing. Any damage other than an occasional small hole shall be repaired by placing another piece of cloth over the damaged part or by completely replacing the cloth. All overlaps whether for repairs or for joining two pieces of cloth shall be a minimum of 1 foot.

4. The stone for the filter and riprap may be placed by equipment. Both filter and riprap shall each be constructed to the full course thickness in one operation and in such a manner as to avoid displacement of the underlying materials. The stone for filter and

riprap shall be delivered and placed in a manner that will ensure that the filter and riprap shall be reasonably homogeneous, with the smaller stones and spalls filling the voids between the larger stones. Riprap shall be placed in a manner to prevent damage to the filter blanket. Hand placing will be required to the extent necessary to prevent damage to the permanent works.

Source and Reference

This specification was prepared from materials furnished by staff of the USDA, Soil Conservation Service and modified by ABAG for simplification and clarity.

15. PERMANENT STORM DRAIN OUTLET PROTECTION

STANDARD

Definition

De-energizing devices and erosion-resistant channel sections between storm drain outlets and stable downstream channels.

Purpose

To convert pipe flow to channel flow and to reduce water velocity in order to convey the flow to a stable existing downstream channel without causing erosion.

Scope

This standard applies to all permanent storm drain outlets.

Conditions Where This Practice Applies

Protection practices apply to storm drain outlets, road culverts, paved channel outlets, etc., discharging into natural or constructed channels that in turn discharge into existing streams or drainage systems. The entire length of the flow path from the end of the conduit, channel or structure to the point of entry into an existing stream or publicly-maintained drainage system is treated. The channel sections may be rock-lined, vegetated, paved with concrete or otherwise made erosion-resistant.

Design Considerations

Design considerations should include the following:

- o depth of flow, roughness, gradient, side slopes, bottom width, discharge rate and velocity of each channel reach between the storm drain outlet and the existing publicly-maintained system or natural stream channel (a channel reach is defined as a length of channel throughout which the hydraulic characteristics do not change);
- o maximum allowable water velocity through each channel reach;
- o type of storm drain outlet protection (aprons, lined waterways, riprap or vegetative protection);
- o compliance with local and state regulations and requirements;
- o maintenance requirements.

Unit Cost Guide

Vegetated channels:	\$0.50-\$ 1.00 per square foot.
Riprap construction:	\$6.00-\$15.00 per linear foot.
Concrete construction:	\$7.50-\$20.00 per linear foot.

Variability in costs is due to size of outlet, topography and availability of materials (as of fall 1979).

Source and Reference

This standard was prepared from materials furnished by staff of the USDA, Soil Conservation Service and modified by ABAG for simplification and clarity.

Design Plans and Specifications

Design plans and specifications for installing storm drain outlet protection should be in keeping with this standard and should describe the requirements for applying the practice to achieve its intended purpose. For alternative methods of design, consult the local Soil Conservation Service office or a qualified engineer.

SAMPLE SPECIFICATIONS FOR PERMANENT STORM DRAIN OUTLET PROTECTION

Design Specifications - Pipe Outlets

All pipe outlets shall have a structurally-lined apron or other suitable de-energizing device immediately downstream from the outlet where the water can change from pipe flow to channel flow. The structurally-lined apron shall meet the following criteria:

1. The bottom grade shall be 0.0%.

2. Side slopes shall be 2:1 or flatter.

3. The top of the sidewall shall extend at least 1 foot above maximum tailwater, but no lower than two-thirds of the vertical conduit dimension above the conduit invert.

4. Invert elevation at the end shall be equal to or lower than the lowest elevation on the cross-section immediately downstream from the end of the apron (i.e., no overfall at the end of the apron).

5. Size of riprap and length of apron shall meet the criteria given in Design of Outlet Protection in Appendix E, and riprap shall meet the Standard and Sample Specifications for Riprap. Concrete paving may be substituted for the riprap. Fifty percent (50%) of the stone size of the riprap mixture, by weight, shall be larger than the median stone diameter.

6. Where there is no well-defined channel immediately downstream from the apron, the width of the end of the apron shall be as follows:

   (a) for tailwater elevation greater than or equal to the elevation of the center of the pipe, W = diameter + 0.4 La,

   (b) for tailwater elevation less than the elevation of the center of the pipe, W = diameter + La, where La is the length of apron determined from the curves in Appendix E.

   Where there is a well-defined channel immediately downstream from the apron, the width of the end of the apron shall be equal to the width of the channel section immediately downstream from the apron.

7. There shall be no bends or curves in the horizontal alignment of the pipe and the apron unless the structure is designed to handle the flow.

8. Tailwater shall be determined by computing depth of flow in the channel reach immediately downstream from the apron by the use of Manning's equation.

Design Specifications - Paved Channel Outlets

Paved channel sections shall meet the following criteria:

1. Velocity in the end of the paved section is no greater than the allowable velocity for the succeeding downstream section.

2. The downstream end of the invert of the paved section shall be no higher than the lowest point in the channel immediately downstream from the end of the paved section (i.e., no overfall at the end of the apron).

3. The end of a paved channel shall merge smoothly with the next downstream channel section, and this transition shall be accomplished within the paved channel. The bottom width of the end of the paved channel shall be at least as wide as the bottom width of the downstream channel. The maximum side divergence of a transition shall be 1 in 3F, where the Froude number, $F=V/\sqrt{gd}$; where V equals velocity in feet per second, d equals depth of flow in feet at the beginning of the transition, and g is acceleration due to gravity (32.2 feet per second).

4. Bends or curves in the horizontal alignment of paved channels are not acceptable unless the Froude number F is 1.0 or less, or the channel is specifically designed to contain the turbulent flow.

Design Specifications - Riprap or Vegetative Protection

Each channel reach having a natural, vegetated or riprap-paved bottom shall be checked for stability by calculating the flow velocity using Manning's equation and ensuring that the channel will handle that velocity without eroding. These computations will necessitate thorough field review and inspection.

Design Specifications - Channel Roughness

For the purpose of design, the roughness coefficient "n" used in calculations shall be as follows:

Channel Lining	"n" Value
Asphaltic concrete - Machine finished	0.018
Hand finished	0.022
Concrete - Float finish	0.015
Unfinished	0.017
Shotcrete, unfinished	0.022
Natural channels not completely lined with vegetation	0.025
Gabion mattresses	0.028
Fabriform - Filter point (waffled surface)	0.025
Riprap	See Standard and Sample Specifications for Riprap
Vegetation	See Standard and Sample Specifications for Grassed Waterway

Design Specifications - Velocities

Maximum flow velocities at design capacity shall be as follows:

Channel Lining	Maximum Velocity (fps)
Natural channels not completely lined with vegetation	
Sand and sandy loam	2.5
Silt loam	3.0
Sandy clay loam	3.5
Clay loam	4.0
Clay, fine gravel and graded loam to gravel	5.0
Graded silt to cobbles	5.5
Shale, hardpan and coarse gravels	6.0
Riprap	See Standard and Sample Specifications for Riprap
Vegetation	See Standard and Sample Specifications for Grassed Waterway

Construction Specifications - Permanent Storm Drain Outlet Protection

1. For natural or vegetated channels, see Standard and Sample Specifications for Grassed Waterway.

2. For riprap construction, see Standard and Sample Specifications for Riprap.

3. Aprons at the end of pipe or lined channel outlets shall meet the following criteria:

   (a) The bottom grade shall be 0.0%.

   (b) Side slopes shall be 2:1 or flatter.

   (c) Sidewalls shall extend up as shown on the plans but not less than two-thirds of the pipe diameter.

   (d) There shall be no overfall from the end of the apron to the surface of the receiving channel. The area to be paved or riprapped shall be undercut so that the invert of the apron shall be at the same grade (flush) with the surface of the receiving channel. The apron shall have a cutoff or toe wall at the downstream end.

   (e) Apron dimensions and riprap size or concrete thickness must be as shown on the plans.

   (f) The width of the receiving end of the apron shall be equal to the bottom width of the receiving channel.

   (g) The placing of fill, either loose or compacted, in the receiving channel shall not be allowed.

   (h) No bends or curves in the horizontal alignment of the apron shall be permitted.

4. Paved channel sections shall meet the following criteria:

   (a) Side slopes, dimensions, grades, etc., shall be as shown on the plans.

   (b) There shall be no overfall from the end of the paving to the surface of the receiving channel.

   (c) Riprap size or concrete thickness, joint details, etc., shall be as shown on the plans.

   (d) The end of paved sections shall be as wide as the receiving channel, and the transition between the two channels shall be smooth.

(e) The placing of fill, either loose or compacted, in the receiving channel shall not be allowed.

(f) Bends or curves in the horizontal alignment of paved channels are not acceptable unless shown on the plans, and the radius of curvature must be the same as shown on the plans.

<u>Source and Reference</u>

This specification was prepared from materials furnished by staff of the USDA, Soil Conservation Service and modified by ABAG for simplification and clarity.

16. GENERAL LAND-GRADING PRACTICES FOR MINIMIZING EROSION

STANDARD

Definition

Reshaping of the existing topography in accordance with a plan as determined by engineering survey and layout.

Purpose

To provide for erosion control and vegetative establishment.

Scope

This standard shall be used for all land grading in urban and suburban areas that do not exceed the limits in the sample specifications.

Conditions Where This Practice Applies

Land grading is done in any area where the existing topography does not suit development or construction for urban or suburban uses.

Design Considerations

Design and installation are based on engineering surveys and investigations.

Design grade and dimension limitations should be suitable for the particular site, conservation system or land use. If other conservation practices are needed to accomplish the stated purpose, they should be included in the plans for improvement. Consideration should be given to erosion hazards when determining slope length and grade.

Unit Cost Guide

Variable, depending on local topography and characterisics of earth to be graded.

Source and Reference

This standard was prepared from materials furnished by staff of the USDA, Soil Conservation Service and modified by ABAG for simplification and clarity.

Design Plans and Specifications

Design plans and specifications for land grading should be in keeping with this standard and should describe the requirements for applying the practice to achieve its intended purpose.

SAMPLE SPECIFICATIONS FOR PERMANENT LAND GRADING TO MINIMIZE EROSION

Design Specifications

The grading plan shall be based upon the incorporation of buildng designs and street layout that fit and utilize existing topography and desirable natural surroundings to avoid extreme grade modifications. Information submitted will provide sufficient topographic surveys and soil investigations to determine limitations that must be imposed on a grading operation related to slope stability, effect on adjacent properties and drainage patterns, measures for drainage, water removal, vegetative treatment, etc.

The plan must also show the existing and propcsed contour of the area or areas to be graded. The plan shall also include practices for erosion control, slope stabilization, safe disposal of runoff water and drainage (such as waterways, lined ditches and reverse slope benches (including grade and cross-section)), grade stabilization structures, retaining walls and surface and subsurface drains. The plan shall also include scheduling and phasing of these practices. The following shall be incorporated into the plan.

1. Provisions shall be made to safely conduct surface runoff to storm drains, protected outlets or stable water courses to ensure that surface runoff will not damage slopes or other graded areas (see Standard and Sample Specifications for Grassed Waterway, Diversion, and Grade Stabilization Structure).

2. Cut and fill slopes shall not be steeper than 2:1. Where the slope is to be mowed, the slope shall be no steeper than 3:1 (4:1 is preferred because of safety factors related to mowing steep slopes).

3. Reverse slope benches or diversions shall be provided whenever the vertical interval (height) of any 2:1 through 5:1 slope exceeds 15 feet. Benches shall be located so as to divide the slope face as equally as possible and shall convey the water to a stable outlet. Soils, seeps, rock outcrops, etc., shall also be taken into consideration when designing benches.

   (a) Benches shall be wide enough to accommodate the construction equipment in use and provide for ease of maintenance.

   (b) Benches shall be designed with a reverse slope of 5:1 or flatter to the toe of the upper slope and with a minimum of 1 foot in depth. Bench gradient to the outlet shall be between 1% and 2%.

   (c) The surface flow across a bench shall not exceed a linear distance of 800 feet (see Standard and Sample Specifications for Diversion).

4. Surface water shall be diverted from the face of all cut-and-fill slopes by the use of diversions, ditches and swales, or conveyed downslope by the use of a designed structure, except that:

(a) The length of overland flow (in feet) to the crest of the slope shall not exceed the distance A given below for any combination of side slopes and vertical intervals.

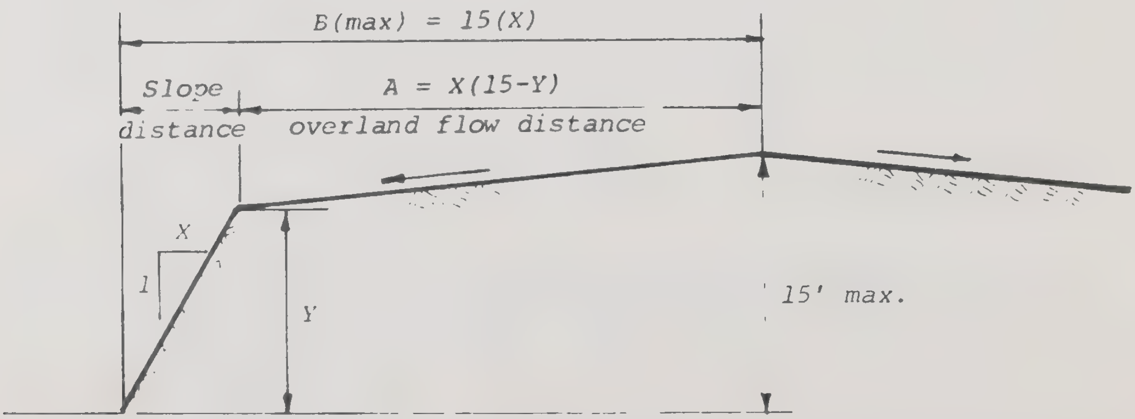
(b) The face of the slope is or shall be stabilized and the face of all graded slopes shall be protected from surface runoff until they are stabilized.

(c) The face of the slope shall not be subjected to any concentrated flows of surface water from natural drainageways, graded swales, downspouts, etc.

The maximum total horizontal overland-flow-plus-slope distance B shall not exceed 15 times the side slope X of the cut or fill slope. Maximum allowable overland flow* distance (in feet) to the top of the slope with no diversion of surface water will be determined by use of the formula A=X(15-Y), where:

- o A = maximum overland flow distance in feet to slope crest;
- o B = maximum horizontal distance in feet (shall not exceed 15X);
- o C = side slope; horizontal distance in feet to 1 foot vertical;
- o Y = vertical interval; height of cut/fill slope in feet measured vertically from bottom elevation of slope to slope crest.

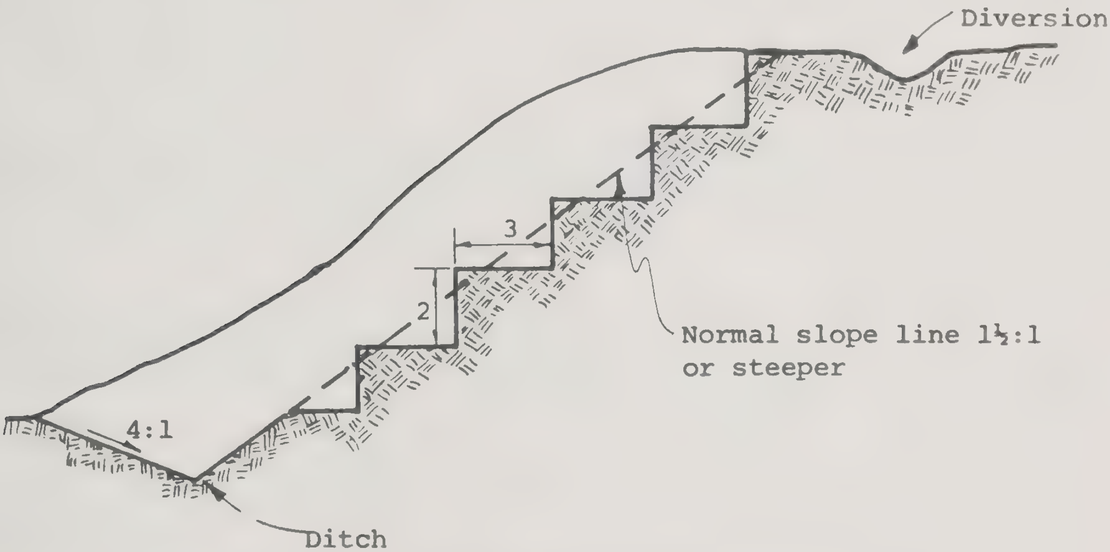
*If maximum allowable overland flow is exceeded, surface water shall be diverted from the slope face and carried to a stable outlet, or conveyed downslope with a designed structure.



TYPICAL SECTION OF A SLOPE*

*from USDA, Soil Conservation Service, Maryland. Standards and Specifications for Soil Erosion and Sediment Control in Developing Areas. July 1975.

5. Serrated cut slopes shall be constructed so as to facilitate long-lasting vegetative stabilization. These serrations shall be made in rippable rock with conventional equipment as the excavation is made. Each step or serrate shall be constructed on the contour and will have steps cut at nominal 2-foot intervals with nominal 3-foot horizontal shelves. These steps will vary depending on the slope ratio of the cut slope. The normal slope line is 1-1/2:1. These steps will weather and act to hold moisture, lime, fertilizer and seed and to produce much quicker and longer lived vegetative cover and slope stabilization. Overland flow shall be diverted from the top of all serrated cut slopes and carried to a suitable outlet.



TYPICAL SECTION OF SERRATED CUT SLOPE*

6. Subsurface drainage shall be provided where necessary to intercept seepage that would otherwise adversely affect slope stability or create excessively wet site conditions that would hinder or prohibit vegetative establishment (see Standard and Sample Specifications for Subsurface Drain).

7. Slopes shall not be created so close to property lines as to endanger adjoining properties without adequately protecting such properties against erosion, slippage, settlement, subsidence or other related damages.

*from USDA, Soil Conservation Service, Maryland. Standards and Specifications for Soil Erosion and Sediment Control in Developing Areas. July 1975.

8. Material for earth fills shall be obtained from designated areas. Except for approved landfills, the fill material shall be free of brush, rubbish, rocks, logs, stumps, building debris and other objectionable material that would interfere with or prevent construction of satisfactory fills. It should be free of stones over 2 inches in diameter where compacted by hand or mechanical tampers, or over 6 inches in diameter where compacted by rollers or other equipment.

9. Stockpiles, borrow areas and spoil areas shall be shown on the plans and shall be subject to the provisions of this standard and specification.

10. All disturbed areas shall be stabilized structurally or vegetatively in compliance with the standard and specifications for the appropriate practices.

Construction Specifications

1. All graded or disturbed areas including slopes shall be protected during clearing and construction in accordance with the approved Erosion and Sediment Control Plan until they are permanently stabilized.

2. All sediment control practices and measures shall be constructed, applied and maintained in accordance with the approved Erosion and Sediment Control Plan and the standards and specifications for the appropriate soil erosion preventive practices.

3. If topsoil is required for the establishment of vegetation, it shall be stockpiled in the amount necessary to complete finished grading of all exposed areas.

4. Areas to be filled shall be cleared, grubbed and stripped of topsoil to remove trees, vegetation, roots and other objectionable material.

5. Areas to be topsoiled shall be scarified to a minimum depth of 3 inches prior to placement of topsoil.

6. All fills shall be compacted as required to reduce erosion, slippage, settlement, subsidence and other related problems. Fill intended to support buildings, structures, conduits, etc., shall be compacted in accordance with local requirements or codes.

7. All fill shall be placed and compacted in layers not to exceed 8 inches per lift.

8. Except for approved landfills, fill material shall be free of brush, rubbish, rocks, logs, stumps, building debris and other objectionable materials that would interfere with or prevent construction of satisfactory fills.

9. Soft, mucky or highly compressible materials shall not be incorporated into fills.

10. All benches shall be kept free of sediment during all phases of development.

11. Seeps or springs encountered during construction shall be handled in accordance with the Standard and Sample Specifications for Subsurface Drain or other approved methods.

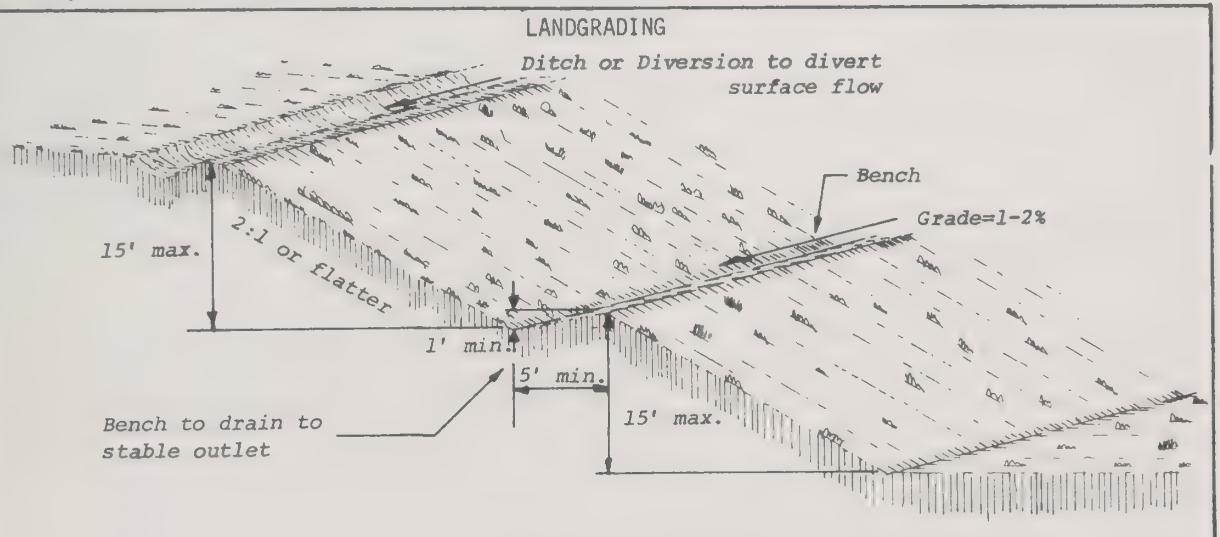
12. All graded areas shall be permanently stabilized immediately following finished grading.

13. Stockpiles, borrow areas and spoil areas shall be shown on the plans and shall be subject to the provisions of this standard and specifications.

Source and Reference

This specification was prepared from materials furnished by staff of the USDA, Soil Conservation Service and modified by ABAG for simplication and clarity.

Sample Drawing: Landgrading



SLOPE DETAIL (WITH BENCH)

(adapted from USDA, Soil Conservation Service, College Park, Maryland. Standards and Specifications for Soil Erosion and Sediment Control in Developing Areas. July 1975.)

17. PERMANENT SUBSURFACE DRAIN

STANDARD

Definition

A conduit, such as tile, pipe or tubing, installed beneath the ground to collect and/or convey drainage water.

Purpose

To improve the soil environment for vegetative growth by regulating the water table and groundwater flow; to intercept and prevent water movement into a wet area; to relieve artesian pressure; to remove surface runoff; to facilitate leaching of saline and alkaline soils; to serve as an outlet for other subsurface drains.

Scope

This standard applies to the design and installation of conduits placed beneath the surface of the ground to provide drainage and reduce erosion.

Conditions Where This Practice Applies

Subsurface drains are used in areas with a high water table where benefits of lowering or controlling groundwater or surface runoff justify installing such a system.

Soil should have enough depth and permeability to permit installation of an effective and economically feasible system. Where soils are saline or alkaline their ability to drain should be considered.

The outlet should be adequate for the quantity and quality of effluent to be disposed. Consideration shall be given to possible damages above or below the point of discharge that might involve legal actions under state or local laws.

Design Considerations

Design considerations should include the following:

- o required capacity;
- o size;
- o depth and spacing;
- o minimum velocity and grade;
- o materials;
- o maximum loading rates;
- o envelopes and envelope material;
- o auxiliary structure and subsurface drain protection.

Unit Cost Guide

Variable, depending on size and design.

Source and Reference

This standard was prepared from materials furnished by staff of the USDA, Soil Conservation Service and modified by ABAG for simplification and clarity.

Design Plans and Specifications

Design plans and specifications for installing subsurface drains should be in keeping with this standard and should describe the requirements for applying the practice to achieve its intended purpose. For alternative design methods and more information, consult the local Soil Conservation Service office or a qualified engineer.

SAMPLE SPECIFICATIONS FOR PERMANENT SUBSURFACE DRAIN

Design Specifications

1. The required capacity shall be determined by one or more of the following:

    (a) Where subsurface drainage is to be uniform over an area through a systematic pattern of drains, a drainage coefficient of 1 inch to be removed in 24 hours shall be used (see drain charts in Appendix F).

    (b) Where subsurface drainage is to be by a random system, a minimum inflow rate of 1.5 cfs per 1,000 feet of line shall be used to determine required capacity.

    For interceptor subsurface drains on sloping land, the inflow rate shall be increased as follows:

Land Slopes	Inflow Rate Increased By
2 - 5%	10%
5 - 12%	20%
over 12%	30%

    (c) Additional design capacity must be provided if surface water is allowed to enter the system.

2. The size of subsurface drains shall be determined from the drain charts in Appendix F. All subsurface drains shall have a nominal diameter which equals or exceeds 4 inches.

3. The minimum depth of cover of subsurface drains shall be 24 inches where possible. The minimum depth of cover may be reduced to a minimum of 12 inches where it is not possible to attain the 24-inch depth and where the drain is not subject to damage by equipment loading or frost action. Roots from some types of vegetation can plug drains as the drains get closer to the surface.

    The spacing of drain laterals shall be dependent on the permeability of the soil, the depth of installation of the drains and the degree of drainage required. Generally, drains installed 36 inches deep and spaced 50 feet from center to center will be adequate. (For more specific information, consult the local Soil Conservation Service office.)

4. The minimum grade for subsurface drains shall be 0.10%. Where surface water enters the system, a velocity of not less than 2 feet per second shall be used to establish the minimum grades. Provisions shall be made for preventing debris or sediment from entering the system by means of filters or collection and periodic removal of sediment from installed traps.

5. Acceptable subsurface drain materials include perforated, continuous, closed-joint conduits of polyethylene plastic, concrete, corrugated metal, asbestos-cement, bituminized fiber and poly-vinyl chloride.

   The conduit shall meet strength and durability requirements of the site.

6. These allowable loads on subsurface drain conduits shall be based on the trench and bedding conditions specified for the job. A factor of safety of not less than 1.5 shall be used in computing the maximum allowable depth of cover for a particular type of conduit.

7. Envelopes shall be used around subsurface drains for proper bedding of the conduit. Not less than 3 inches of envelope material shall be used for sand-gravel envelopes. Where necessary to improve the characteristics of flow of groundwater into the conduit, more envelope material may be required.

   Envelope material shall be placed to the height of the uppermost seepage strata. Behind bulkhead and retaining walls, it shall go to within 12 inches of the top of the structure. This does not cover the design of filter materials where needed.

   Materials used for envelopes shall not contain materials which will cause an accumulation of sediment in the conduit or render the envelope unsuitable for bedding of the conduit. Envelope materials shall consist of sand-gravel material, of which all shall pass a 1.5-inch sieve, 90% to 100% shall pass a 0.75-inch sieve, and not more than 10% shall pass a No. 60 sieve.

   The conduit shall be placed and bedded in a sand-gravel envelope. A minimum depth of 3 inches of envelope material shall be placed on the bottom of a conventional trench. The conduit shall be placed on this, and the trench completely filled with envelope material to a minimum depth of 3 inches above the conduit.

   Soft or yielding soils under the drain shall be stabilized where required, and lines shall be protected from settlement by adding gravel or other suitable material to the trench by placing the conduit on a plank or other rigid support, or by using a long section of perforated or water-tight pipe with adequate strength to ensure satisfactory subsurface drain performance.

8. The outlet shall be protected against erosion and undermining of the conduit, against damaging periods of submergence and against entry of rodents or other animals into the subsurface drain (see drawing for animal guard in Appendix F.)

A continuous 10-foot section of corrugated metal, cast iron, or steel pipe without perforations shall be used at the outlet end of the line and shall outlet above the normal elevation of low flow in the outlet ditch or above mean high tide in tidal areas. No envelope material shall be used around the 10-foot section of pipe. Two-thirds of the pipe shall be buried in the ditch bank, and the cantilevered section shall extend to a point above the toe of the ditch side slope, or the side slope shall be protected from erosion.

Conduits under roadways and embankments shall be water-tight and designed to withstand the expected loads.

Where surface water is to be admitted to subsurface drains, inlets shall be designed to exclude debris and prevent sediment from entering the conduit. Lines flowing under pressure shall be designed to withstand the resulting pressures and velocity of flow (see surface water inlet drawing in Appendix F.) Surface waterways shall be used where feasible.

The upper end of each subsurface drain line shall be capped with a tight-fitting cap of the same material as the conduit or other durable material, unless connected to a structure.

Construction Specifications

1. Deformed, warped or otherwise damaged pipe or tubing shall not be used.

2. All subsurface drains shall be laid to a uniform line and covered with envelope material. The pipe or tubing shall be laid with the perforations down and oriented symmetrically about the vertical centerline. Connections will be made with manufactured functions comparable in strength with the specific pipe or tubing unless otherwise specified. The method of placement and bedding shall be as specified on the drawing.

3. Envelope material shall be a sand-gravel material, of which all shall pass the 1.5-inch sieve, 90% to 100% shall pass the 0.75 inch sieve, and not more than 10% shall pass the No. 60 sieve.

4. The upper end of each subsurface drain line shall be capped with a tight-fitting cap of the same material as the conduit or other durable material, unless connected to a structure.

5. A continuous 10-foot section of corrugated metal, cast iron or steel pipe without perforations shall be used at the outlet end of the line. No envelope material shall be used around the 10-foot section of pipe. An animal guard shall be installed on the outlet end of the pipe.

6. Earth backfill material shall be placed in the trench in such a manner that displacement of the drain will not occur.

Source and Reference

This specification was prepared from materials furnished by staff of the USDA, Soil Conservation Service and modified by ABAG for simplification and clarity.

E. ENFORCEMENT

The ordinance, the handbook of standards and specifications, and the erosion and sediment control plans are the written requirements of the regulatory program. Once these are in place, it should then be the responsibility of the site inspector to see that erosion and sediment are controlled on the actual site.

The following guidelines, based on current practices in Fairfax County, Virginia, are a checklist for site inspectors to help them obtain compliance with regulations and deal with violations. It is recommended that local cities and counties adopt these or similar enforcement guidelines as official public works procedures.

ENFORCEMENT GUIDELINES FOR ON-SITE EROSION AND SEDIMENT CONTROL

The site inspector should follow the procedures outlined below to ensure on-site compliance with regulations for erosion and sediment control.

1. Initial Site Review (Preconstruction Meeting)

   Prior to the start of work, meet the field superintendent at the site to review plan requirements. Go over the planned construction sequence and the corresponding schedule for installation of erosion and sediment control measures to see that the superintendent has thought through all phases of the job. Go over all the notes. Look at the problem areas with him such as steep slopes above ponds and streams. On sites where soil may be particularly erodible, it is recommended that an SCS or RCD advisor or soils engineer accompany the inspector on the first site visit. Consult the USDA Soil Conservation Service field offices in Concord, Dixon, Gilroy, Half Moon Bay, Livermore, Napa, Petaluma, San Jose or Santa Rosa for availability of SCS personnel.

   Review the planned control measures with attention to these items:

   (a) Siting Adjustments. Locations of control measures in the plans may have to be adjusted to fit actual site conditions. If the controls do not make good sense, it is the inspector's responsibility to see that necessary adjustments are made. In addition, these changes should be brought to the attention of the department supervisor.

   (b) Alterations to Timing and Measures. Judgment must be exercised in allowing or requiring changes as construction progresses. If the actual construction schedule varies from that specified in the grading plan, changes in control measures may be necessary.

2. Start of Work

   (a) Erosion and sediment controls (dikes, dams, etc.) should be placed prior to or as the first step in grading if grading begins in the rainy season.

   (b) Dikes, stockpiles and dams should be seeded for temporary vegetative cover and mulched before September 15. Urge the contractor to use excavated top soil for berm or dike material. This provides an out-of-the-way stock pile which is easily vegetated.

   (c) Read the weather reports. See that the superintendent is ready for rain when it starts. Contractors are seldom prepared for rain, particularly the first rain.

(d) Visualize runoff patterns during a heavy rain. Be sure that streams and storm drains below the site will not be damaged by runoff from such a storm.

(e) See that unpaved site-access roads that drain to existing roads have interceptors to prevent soil from being deposited onto the existing roads.

(f) Ensure that the superintendent has an information program to keep equipment operators aware of the locations and requirements for control measures so that they do not unintentionally destroy them. Likewise, there should be a program to keep vehicles, equipment and materials out of areas that do not have to be disturbed.

3. Construction Continuation

(a) Inspector-Superintendent Relationship. Maintain communications with the superintendent; the job cannot run well without mutual cooperation. Ask about progress reports. Ask him to prepare for removing controls as work approaches completion (if they need to be removed). The inspectors should deal with the superintendent, not his subcontractors. If the superintendent is habitually not available, contact the developer or owner.

(b) Maintenance. Check maintenance of existing erosion controls; all sediment basins and traps need cleanout, and diversions need periodic reshaping and dressing. All dams should have a specified cleanout level which the inspector should be able to recognize. During the rainy season, dams and berms cut through for utilities should be restored as soon as possible. Make a special check whenever rain is forecast and see that the superintendent has designated someone to check control measures daily and to make repairs.

(c) Storm Drainage System. Watch development of the storm drainage system. As soon as any pipe is in the ground, manholes, inlet structures and walls should be installed so that proper controls can be built and the area will not have to be torn up again. As the system is built, attention must be turned to preventing sediment from entering the system. The volumes and velocities of water coming from drainage structures are generally too great to control there; the control should be shifted to the inlets. As the site progresses, the inlet protection should change from excavated silt traps to rock filters at the inlets or other equivalent measures. Do not use straw bales at inlets or outlets at any time. Do not ever allow inlets to be blocked.

(d) Construction Drainage. The site should drain so that it can be worked, but it should drain slowly so that a minimum of soil will be washed off-site. Ensure drainage of all traps. Every basin, from the one behind a large dam to the one at a storm sewer inlet, must drain. Standing water is a hazard, a nuisance to construction and a problem for compaction. If water remains ponded longer than 24 hours, see that drains and filters are cleaned out and reshaped.

Particular care is required if the construction is close to occupied buildings. Inlet protection that prevents the inlet from functioning could cause flooding of adjacent properties. Major sediment basins attract children, and fencing is almost mandatory if there are occupied houses within 200 yards. Even with fencing, early drainage of each pond after a storm is necessary to reduce the possibilities of accidents.

(e) Fall Seeding. Remind the contractor of the requirements for seeding and mulching. Tell him to get advice on this from the District Conservationist. Seeding equipment should be ready to go right after fine grading and seedbed preparations.

All seed and mulch should be in place by September 15. Check contractor's preparations to meet this deadline. Make the contractor keep all controls operative until all the area above each control is fully stabilized. Seedbeds should be seeded the same day they are prepared. This practice will prevent the need for regrading and replacing topsoil on slopes.

(f) Stockpiles. Stockpiles of soil that are not shown in the plans are commonly created and usually remain a long time. During the rainy season, all stockpiles should be seeded as soon as they are created. A diversion should be established above each stockpile. Do not let contractor cover up controls or bury trees with these spoils.

(g) Compaction. Poor compaction of berms, dams and fill slopes leaves highly erodible soil masses. Get the contractor to walk-in all fills in low lifts with tracked equipment or compactors. Cleat marks should be on the contour.

4. Construction Completion

(a) Restoration. Ensure that all sediment dams, berms and other controls are removed, regraded, seeded and mulched before demobilization. If any silt dam is to be left in place permanently (as shown on the plan), see that it is

cleaned out, and the embankment and bottom covered with a good stand of grass. Many diversions may be left in place, but authorization should be obtained from the permit-issuing agency.

(b) Cleanup. Insist that any areas disturbed during final cleanup be seeded and mulched at once.

5. Violations

(a) First inform superintendent and developer verbally that they are not in compliance.

(b) If action is not taken within the specified time (a practical time for making necessary corrections), issue a written violation notice to the developer.

(c) The violation notice must contain the following:

- citation of the pertinent ordinance;
- description of what the violation is and what must be done to correct it;
- deadline for correction;
- signature of inspector.

(d) Submit one copy to the department supervisor and one copy to the developer. (To eliminate criticism from developers, it is advisable for the inspector or his supervisor to give notice of the violation to the superintendent on-site the same day the violation is written. This procedure gives the developer the benefit of the full amount of time granted for correction.)

(e) Follow-up on the violation notice with a site inspection on the last day allowed for correction or one or two days thereafter. Fill out a Violation Status Report which either releases the violation if the work has been done, or indicates that the work has not been done and makes a recommendation for further action.

(f) Submit copies of the Violation Status Report to both the department supervisor and the developer.

The department supervisor should then take appropriate action pursuant to the Erosion and Sediment Control Ordinance.

II. URBAN RUNOFF POLLUTION CONTROL

This Chapter contains standards for public works practices designed to reduce pollutants entering water bodies in urban runoff. The standards are based on practices found, through mathematical modeling and analysis of local and national data, to result in water quality benefits. Used to review present practices, these Best Management Practices (BMPs) would provide local jurisdictions with a means of reducing pollution in urban runoff at little or no additional cost.

A number of related public works practices are not included among the standards presented below. In the analysis of water quality data, it was not found that specifying BMPs for such practices as street surface maintenance, street cleaning equipment selection and litter control would yield significant water quality benefits over present practices.

In general, public works practices are designed to satisfy a number of objectives, such as aesthetics, property protection and public health. However, the standards that follow are formulated in terms of water quality benefits alone; other benefits or objectives that might result have not been considered.

1. SCHEDULING STREET CLEANING TO MINIMIZE SOLIDS WASHOFF

STANDARD

Definition

Scheduling of seasonal cleaning of streets in urban areas.

Purpose

To reduce the amount of solids that would be washed off the street into storm sewers.

Scope

This standard applies to curbed streets in urban areas that are cleaned by street cleaners and drained by storm sewers discharging directly or indirectly to surface waters without intervening treatment.

Conditions where this Practice Applies

All streets within the scope of this practice should be cleaned according to this standard. On some streets, other considerations such as aesthetics or safety may warrant more frequent cleaning.

Design Considerations

The most cost-effective street cleaning schedule for any budget level or amount of solids prevented from washing off should be determined using the Street Solids Washoff Model given in Appendix G. Values for the model inputs should be used that reflect, as accurately as feasible, conditions in the areas for which cleaning is being scheduled. Input should include values for the following:

- number of design areas;
- number of land uses (same in all design areas, i.e., residential, commercial, industrial);
- name of each design area;
- name of each land use;

- average street solids load before cleaning for each location and land use;
- daily solids-accumulation rate for each location and land use as a function of the solids load on the street at the beginning of the day;
- street cleaning efficiency for each location and land use;
- street cleaning cost for each location in dollars per curb mile per pass;
- number of curb miles for each location and land use;
- threshold rainfall in inches per day below which intensity no solids washoff is assumed to occur (this value is typically 0.2 inches per day except in special circumstances (Pitt, 1979));
- daily rainfall record in inches per day for four years considered typical for the area being modeled (fewer years of record may be used with minor adjustments to the computer program);
- rainfall adjustment factor for each location.

Benefits

By scheduling street cleaning operations to meet water quality objectives, program effectiveness can often be improved by a factor of two over typical programs. That is, for the same expenditure, twice the amount of solids can be prevented from washing off the streets, or the same amount of solids can be prevented from washing off the streets for half the cost. These savings, however are approximate and depend upon the existing street cleaning schedule.

Table II.1.1 illustrates the differences in the cost per pound of street solids prevented from washing off San Jose streets under various conditions. (The complete analysis for San Jose is given in Appendix G.) In all Bay Area locations, street cleaning during the wet season is much more cost effective than cleaning during the dry season.

Unit Cost Guide

Sample unit costs based on San Jose data are given in Appendix G. Unit costs may vary widely depending upon the cleaner performance and solids accumulation rate for a given jurisdiction. Many street cleaning schedules could be revised to redistribute rather than to expand the street cleaning effort. Such schedule changes should not incur added costs.

TABLE II.1.1 UNIT COST OF PREVENTING STREET SOLIDS FROM WASHING OFF THROUGH STREET CLEANING: SAN JOSE BREAKDOWN BY LAND USE AND SEASON

	Season	Land Use	Cleaning Frequency	Unit Cost ($ per pound prevented from washing off)
1	wet	industrial	monthly	.07
2	wet	industrial	biweekly	.09
3	wet	commercial	monthly	.11
4	wet	commercial	biweekly	.13
5	wet	industrial	weekly	.14
6	wet	residential	monthly	.16
7	wet	residential	biweekly	.18
8	wet	commercial	weekly	.18
9	wet	residential	weekly	.23
10	wet	industrial	daily	.54
11	wet	commercial	daily	.57
12	wet	residential	daily	.64
13	dry	residential	monthly	5.74
14	dry	residential	biweekly	6.20
15	dry	commercial	monthly	6.67
16	dry	residential	weekly	7.05
17	dry	commercial	biweekly	7.18
18	dry	commercial	weekly	8.13
19	dry	industrial	monthly	8.24
20	dry	industrial	biweekly	8.97
21	dry	industrial	weekly	10.35
22	dry	residential	daily	16.63
23	dry	commercial	daily	18.54
24	dry	industrial	daily	25.55

(The wet season was assumed to be September through March and the dry season April through August.)

Sources and References

This standard was prepared by ABAG based on the following sources:

1. J.B. Gilbert and Assoc. Water Quality Control Investigation: Urban Runoff, Construction Activities, Agricultural Practices, Appendix 2.1-1. Prepared for Southern California Association of Governments. August 1978.

2. Pitt, Robert. Demonstration of Nonpoint Pollution Abatement through Improved Street Cleaning Practices. Prepared for the U.S. Environmental Protection Agency, Grant No. S-804432. 1979.

3. Russell, Peter. Regional Evaluation of Street Sweeping as a Water Quality Control Measure. Water Quality Technical Memorandum No. 38. Association of Bay Area Governments. 1980.

2. PARKING RESTRICTIONS DURING STREET-SWEEPING OPERATIONS

STANDARD

Definition

Restrictions on curb-side parking or standing during street-sweeping operations.

Purpose

To permit economical removal of additional amounts of solids from street surfaces; to provide street cleaning vehicle access to curb lanes.

Scope

This standard applies to curbed streets in urban areas that are cleaned by street-cleaning vehicles and drained by storm sewers, and where no other considerations preclude such restrictions.

Conditions where this Practice Applies

The analytic methodology described here should be used by each jurisdiction to identify streets where parking and standing restrictions are cost effective. Factors in the analysis are the sweep efficiencies and the unit cost of solids removal with and without the parking restrictions.

For streets serviced by street cleaning vehicles, the following values must be estimated as accurately as is feasible:

- o the annual sweeping frequency (f): the number of passes the street-cleaning vehicle makes on each curb on the street each year;
- o current total cost (CC): cost of sweeping one curb mile once (two curb miles per street mile);
- o annual total implementation cost (IC): cost per curb mile of posting and maintaining signs and markings that indicate parking or standing restrictions and times during which restrictions are in effect;
- o comprehensive enforcement costs (EC): costs per curb mile for each time the sweeper services the street;
- o typical curb occupancy during hours when sweeper services the street;

- o typical long-term curb occupancy (24 hours per day);
- o current total street solids removed (CR): percent of total solids load on the street, with no parking controls and with the sweeper moving around cars as necessary (if local data are not readily available, Table II.2.1 should be consulted to obtain CR corresponding to existing curb occupancy);
- o potential street solids removed (RR): percent of total solids load on the street, with parking controls and with the sweeper moving next to the curb (if local data are not readily available, Table II.2.1 should be consulted to obtain RR corresponding to existing curb occupancy).

TABLE II.2.1

INFLUENCE OF PARKED CARS ON STREET-SWEEPING EFFECTIVENESS

Normal Percentage of Curb Occupied by Parked Cars	Percentage of All Solids Removed with Parking Restrictions and Sweeper Operated in Curb Lane, RR	Percentage of All Solids Removed with No Parking Restrictions and with Sweeper Moving Around Parked Cars as Necessary, CR	Improvement in Percentage of All Solids Removed with Parking Restrictions
0	50	50	0
10	49	42	7
20	48	36	12
30	47	31	16
40	46	26	20
50	45	21	24
60	43	19	24
70	39	16	23
80	35	18	17
90	28	23	5
100	0	50	-50
80% for 24 hours	30	19	11
90% for 24 hours	0	43	-43
100% for 24 hours	0	50	-50

Using the variable values appropriate for each street, the following formula should be used to calculate the ratio of the unit cost of removing additional street solids as a result of imposing parking restrictions to the unit cost of removing street solids without such restrictions:

$$\frac{\dfrac{(IC/f) + EC}{RR - CR}}{\dfrac{CC}{RR}} = \frac{\text{unit cost of increased removal due to restrictions}}{\text{current unit cost}} = \text{unit removal cost ratio.}$$

The definitions of variables assigned above apply in this equation. For streets where the value of the equation is less than 1 but greater than 0, solids can be swept at a lower cost per pound removed with parking restrictions than without such restrictions. This analysis ignores revenues generated through citations of parking restriction violators. These revenues would further favor the imposition of parking restrictions.

When the results of the analysis indicate parking restrictions would be cost efficient (when the equation evaluates to greater than 0 but less than 1), the jurisdiction should then determine whether such restrictions are compatible with other policies and planning goals. Some pertinent considerations are litter control, traffic flow, availability of alternative parking sites and the development or availability of mass transit in the affected areas.

Design Considerations

Where appropriate, an enforceable parking ordinance should be adopted. The Model Parking Ordinance which follows is an example of an effective ordinance that may be adopted in its entirety or incorporated into a pre-existing general ordinance.

Benefits

The benefits of parking restrictions are shown, using typical sweep efficiencies, in Table II.2.2. As the precise unit removal cost ratio obtainable by a jurisdiction may vary somewhat from the values shown, local data should be used when available. It should be noted that with high curb occupancy, negative benefits accrue when parking restrictions are implemented.

Unit Cost Guide

The following cost figures are approximate and may range substantially among jurisdictions.

Posting and maintaining restricted parking signs: $182 per curb mile per year (J.B. Gilbert and Assoc., 1978).

Enforcement of parking restrictions: $0.23 per curb mile per sweep (J.B. Gilbert and Assoc., 1978).

Revenue from parking citations: $12.25 per curb mile per sweep (assuming 245 parking spaces per curb mile; route is patrolled and citations issued every other time the sweeper passes; a $10.00 citation is collected from 1% of the spaces each time the area is patrolled.)

TABLE II.2.2

UNIT REMOVAL COST RATIO FOR ENFORCED PARKING RESTRICTIONS

Percentage of Curb Length Occupied	Current Sweeping Costs = $7 per Curb Mile			Current Sweeping Costs = $12 per Curb Mile		
	Sweeping Frequency			Sweeping Frequency		
	Daily	Weekly	Monthly	Daily	Weekly	Monthly
10	0.80	3.20	13.20	0.47	1.87	7.70
20	0.40	1.60	6.60	0.23	0.93	3.85
30	0.26	1.03	4.26	0.15	0.60	2.49
40	0.17	0.69	2.86	0.10	0.40	1.67
50	0.12	0.47	1.92	0.07	0.27	1.12
60	0.11	0.42	1.74	0.06	0.25	1.02
70	0.09	0.37	1.53	0.05	0.22	0.89
80	0.14	0.56	2.33	0.08	0.33	1.36
90	0.61	2.45	10.12	0.36	1.43	5.90
100	*	*	*	*	*	*
80% for 24 hrs.	0.23	0.92	3.80	0.13	0.54	2.22
90% for 24 hrs.	*	*	*	*	*	*
100% for 24 hrs.	*	*	*	*	*	*

(Note: The table entries are unit removal cost ratios using the values in Table II.2.1 with the equation and the cost assumptions given herein.)

*Negative ratio due to lowered solids removal with parking restrictions.

Sources and References

The standard was prepared by ABAG based on the following sources:

1. Bursztynsky, T. A. Evaluation of Using Parking Restrictions to Increase Street Sweeping Effectiveness. Water Quality Technical Memorandum No. 45. Association of Bay Area Governments. 1980.

2. J.B. Gilbert and Assoc. Water Quality Control Investigation: Urban Runoff, Construction Activities, Agricultural Practices, Appendix 2.1-1. Prepared for Southern California Association of Governments. August 1978.

3. Pitt, Robert. Demonstration of Nonpoint Pollution Abatement through Improved Street Cleaning Practices. Prepared for U.S. Environmental Protection Agency, Grant No. S-804432. 1979.

MODEL PARKING ORDINANCE TO INCREASE STREET-SWEEPING EFFECTIVENESS

100.00 Title. This Chapter shall be known as the "[City] Parking Restrictions for Street Sweeping" and may be so cited.

100.01 Purpose. The purpose of this Chapter is to improve the effectiveness of street-sweeping operations in removing street solids through the implementation of parking restrictions.

100.02 Definitions. Whenever any words or phrases used in this Chapter are not defined in this Section, but are defined in the Vehicle Code of the State of California and amendments thereto, the Vehicle Code definitions shall apply.

The following words and phrases when used in this ordinance shall, for the purpose of this ordinance, have the meanings respectively ascribed to them in this Section.

(a) Curb Occupancy. The percentage of the curb length occupied by parked vehicles.

(b) Hour(s). Whenever certain hours are named herein, they shall mean standard time or daylight saving time as may be in current use in this city.

(c) Official Traffic Control Devices. All signs and markings placed or created by authority of the Director of [ ] (hereinafter "Director") under this Chapter.

(d) Park. To stand or leave standing a vehicle, whether occupied or not, otherwise than temporarily for the purpose of and while actually engaged in the loading or unloading of passengers or materials.

(e) Police Officer. Every officer of the Police Department of this city or any other person authorized to direct or regulate traffic or to make arrests for violations of traffic regulations.

(f) Stand. When prohibited means any stopping of a vehicle, and leaving same unattended, except when necessary to avoid conflict with other traffic or in compliance with the directions of a police officer or official traffic control device.

(g) Street. Street is a way or place of whatever nature, publicly maintained and open to the use of the public for purposes of vehicular travel; except a street is not a highway and a highway is not a street.

201.01 Application of Regulations. The provisions of this Chapter prohibiting the standing or parking of a vehicle shall apply during those hours herein specified, except when it is necessary to stop a vehicle to avoid conflict with other traffic or in compliance with the directions of a police officer or official traffic control device.

201.02 No Standing and No Parking Areas. The Director shall designate pursuant to §301.01 areas wherein neither parking nor standing shall be allowed during specified hours.

No operator of any vehicle shall stand, park or leave standing said vehicle in area designated by the Director pursuant to this section and §301.01, and for which area the Director has established appropriate signs or markings pursuant to §201.03.

201.03 Director to Establish and Maintain No Standing Zones and No Parking Areas. The Director shall establish and maintain, by appropriate signs or markings, all no standing and no parking areas as defined and described in this Chapter and shall give notice by appropriate signs or markings that vehicles parked or left standing in violation of such prohibitions are subject to removal from the street.

201.04 Violations. When signs or markings described in §201.03 are in place, it shall be unlawful and shall constitute an infraction for any operator of a vehicle to stand or park said vehicle in violation of said sign or marking.

201.05 Penalties. Every person convicted of a violation of this Chapter shall be deemed guilty of an infraction and shall be punished by a fine not to exceed $[ ].

201.06 When Vehicles May Be Removed from Streets. Any police officer may remove or cause to be removed any vehicle parked or left standing upon a street when such parking or standing is prohibited by this Chapter and signs or markings giving notice of such prohibition and of such removal are in place. The operator(s) or owner(s) of record of such vehicles shall pay the reasonable cost of removing the vehicle.

301.01 Designation of No Parking and No Standing Areas. The Director shall designate each street named by the [City Council of] as a no standing and no parking zone during the hours said street may be serviced by a mechanical street sweeper. Such hours for each street shall be set forth in a schedule of street-sweeping operations submitted to the Director and may be amended from time to time.

3. STREET SURFACE MATERIAL SELECTION

STANDARD

Definition

Selection of paving material used to surface permanent streets and roads.

Purpose

To minimize surface runoff pollution from street surfaces by using pavement types correlated with significantly lower rates of water contaminant accumulation.

Scope

This standard applies to selection of paving material for permanent streets whose stormwater runoff enters surface waters either directly or indirectly without intervening treatment.

Conditions where this Practice Applies

This standard should be applied when asphalt and concrete are being considered as street surface paving materials and other factors such as first cost, maintenance, energy requirements or traffic safety do not present overriding considerations.

Design Considerations

Concrete rather than asphalt, should be used as the street surface paving material when consideration of all other pertinent factors does not clearly indicate an otherwise superior choice. Additional factors which may influence street surface paving material selection include first cost, maintenance costs, energy requirements and traffic safety. An extensive statistical analysis of both national and San Francisco Bay Area street surface contaminant data yielded highly significant correlations between the street surface material used and the accumulation rates of some heavy metals. Analysis included consideration of land use, season, region of the country, condition of the pavement and average daily traffic. The statistical results do not exclude the possible existence of other factors which influence contaminant accumulation rates and which are correlated with the street surface material type. Despite the lack of a definitive cause and effect relationship between asphalt street surfaces and high pollutant accumulation rates, the probable water quality benefits of concrete street surfaces should be considered in street paving material selection.

Benefits

The ratios of the mass water pollutant accumulation rates for contaminants found to vary significantly between asphalt and concrete street surfaces are shown on Table II.3.1.

TABLE II.3.1

Parameter	Asphalt Surface Accumulation Rate/ Concrete Surface Accumulation Rate
Total solids	2.7
Chromium	4.3
Iron	4.4
Copper	3.8
Zinc	3.7
Lead	5.2
Manganese	3.2
Cadmium	3.0
Nickel	3.3

These accumulation rate ratios are for equivalent land uses.

Sources and References

This standard was prepared by ABAG based on the following sources:

1. Amy, G., et al. Water Quality Management Planning for Urban Runoff. U.S. Environmental Protection Agency, EPA 440/9-75-004. 1974.

2. Russell, Peter. The Influence of Street Surface Type and Condition on Street Solids Loading Rate and Composition. Water Quality Technical Memorandum No. 40. Association of Bay Area Governments. 1980.

4. CATCH-BASIN CLEANING AS A SURFACE RUNOFF CONTROL MEASURE

STANDARD

Definition

Removal of solid and liquid contents of catch basins serving storm sewers.

Purpose

To prevent pollutants accumulated in catch basins from reaching surface waters.

Scope

This standard applies to catch basins in urban areas that discharge through storm sewers to surface waters. Catch basins on combined sewer systems and on storm sewer systems that incorporate treatment processes for pollutant removal are not covered by this standard. This standard does not apply to storm sewer inlets without sumps.

Conditions where this Practice Applies

This standard should be applied to all catch basins within the scope of this standard.

Design Considerations

A recent study has suggested that catch-basin cleaning can prevent surface runoff pollutants from reaching surface waters at a lower unit cost than street cleaning (Dietrich and Davis, 1980). The study recommended, however, that a more refined analysis be undertaken. On the basis of the preliminary analysis, catch-basin cleaning should be conducted.

At each cleaning, as much solid and liquid content as possible should be removed and as little as possible allowed to enter the storm sewer (which rules out flushing as an acceptable method). Adequate information is not available to recommend a specific catch-basin cleaning method at present. Each jurisdiction should use the method that best suits the resources available.

The preliminary catch-basin analysis indicates that no increase in the percentage removed of the total amount of material entering the basin is obtained using cleaning frequencies greater than twice annually. Catch basins should be cleaned twice per year and normally should be at least one-half full before cleaning.

Benefits

Pollutants occur in both the liquid and solid fractions of the catch-basin contents. The estimated average 5-day biochemical oxygen demand in the liquid fraction of catch-basin contents is 60 grams (Dietrich and Davis, 1980). Without cleaning, most of this load would be washed into the storm sewer by a moderate storm. The typical solids content of a catch basin is between 2,500 and 5,000 pounds. (Dietrich and Davis, 1980). Removing solids allows the basin to catch more solids during the next storm, thus preventing them from reaching surface waters.

Unit Cost Guide

Cleaning costs average about $20 per basin, and 125 to 250 pounds of solids per cleaning dollar are removed (Dietrich and Davis, 1980). These costs do not include expenses incurred in disposing of the removed materials.

Source and Reference

This standard was prepared by ABAG based on the following source:

1. Dietrich, William F. and John A. Davis. Catch Basin and Storm Sewer Cleaning as Surface Runoff Control Measures. Water Quality Technical Memorandum No. 49. Association of Bay Area Governments. 1980.

5. STORM SEWER INLET CLEANING

STANDARD

Definition

Cleaning of storm sewer inlets without sumps specifically designed to trap solids.

Purpose

To reduce surface runoff pollution by removing accumulated solids from inlets to storm sewer systems.

Scope

This standard applies to inlets on urban storm sewers draining directly or indirectly to surface water without intervening treatment and without sumps to collect solids (see Catch-Basin Cleaning).

Conditions where this Practice Applies

All inlets in urban areas comparable to Oakland should be cleaned according to this standard. Due to lack of information, inlets in suburban or semi-rural areas are not included in this standard.

Design Considerations

A program for cleaning inlets should include the following considerations:

- o accumulation rate of solids;
- o design of inlet;
- o rainfall season;
- o method of cleaning, i.e., manual or vacuum.

Benefits

A sampling of 20 inlets in Oakland, California showed solids accumulation ranging from 13 to 163 pounds per inlet, with an average of 57 pounds (Dietrich and Davis, 1980). The weighted averages of the solids constituents included 16% chemical oxygen demand (COD), 0.03% nitrogen, 0.1% phosphorus, and 0.1% lead. Inlets appear to be less effective than catch basins in retaining pollutants.

Unit Cost Guide

According to a survey of inlet cleaning costs conducted in fall 1979 (Dietrich and Davis, 1980), each cleaning ranged from $4.00 to $17.00 per inlet. There was no correlation between cleaning method and reported cost. Based upon an average inlet content of 57 pounds of solids, inlet cleaning could cost between $.07 and $.30 per pound of solids removed.

Source and Reference

This standard was prepared by ABAG based on the following source:

1. Dietrich, William F. and John A. Davis. Catch Basin and Storm Sewer Cleaning as Surface Runoff Control Measures. Water Quality Technical Memorandum No. 49. Association of Bay Area Governments. 1980.

6. LEAF REMOVAL

STANDARD

Definition

Collection of leaves and other waste products of urban vegetation for disposal.

Purpose

To prevent pollution of surface waters from release of nutrients and/or consumption of oxygen in the natural decomposition of leaves and vegetation. (Decomposition of these materials on land enriches the soil but when occurring in surface waters, can impair beneficial uses.)

Scope

This standard applies in urban areas where fallen leaves and other dead vegetation may enter storm sewers.

Conditions where this Practice Applies

Target materials are those leaves and related non-growing vegetation falling on lawns, driveways or other landscaped areas that would be swept onto the street and those falling directly onto streets and sidewalks.

Design Considerations

Leaves and other vegetation falling directly onto streets should be collected by customary street-sweeping methods. Although collection of other leaves covered by this standard is recommended, adequate information to assess which method is best from an environmental and economic perspective is not available. Typically, leaves are collected by either manual or mechanical methods. The manual method entails loading piled leaves onto trucks. Bagging of the leaves is often required to facilitate handling. Mechanical methods include: (1) using a street sweeper, with or without a trash-screen mounted on the front to push leaves into piles for loading; (2) using front-end loaders to collect leaf piles and load them into trucks; and (3) using a vacuum truck.

Combining leaf collection with regular garbage collection, except possibly during the heavy leaf-fall season, may be most appropriate for many communities. Additional effort will probably be necessary in autumn.

Benefits

Collecting fallen leaves and dead vegetation prevents nutrient loading and oxygen consumption in the receiving water bodies. Although decay rates vary with vegetation type, complete decomposition releases nearly all of the nitrogen and phosphorus present to the water body. The nitrogen content of leaves is usually 0.5% to 2.5% of dry weight. The posphorus content ranges from 0.07% to 0.25% of dry weight. The amount of dissolved oxygen removed from the water during complete decomposition of leaves is 50% to 75% of leaf dry weight.

Unit Cost Guide

Leaves collected by vacuum truck: $0.06 per pound.
Pickup of bagged leaves in residential areas: $0.04 per pound.

Sources and References

This standard was prepared for ABAG based on the following source:

1. Dietrich, William F. and John A. Davis Leaf Removal as a Surface Runoff Control Measure. Water Quality Technical Memorandum No. 57. Association of Bay Area Governments. 1980.

APPENDICES

USDA-Soil Conservation Service-Md

July 1975

STANDARD AND SPECIFICATIONS
FOR
PROTECTIVE MATERIALS
FOR CHANNELS AND STEEP SLOPES

Definition

Installing jute or excelsior mattings on a prepared seed - or planting - bed of a channel or steep slope to be stabilized with vegetation.

Purpose

As an aid to controlling erosion on critical sites during establishment period of protective vegetation.

Conditions Where Practice Applies

In channels where designed flow exceeds 3.5 feet per second; on short, steep slopes where erosion hazard is high and planting is likely to be slow to establish adequate protective cover; on tidal - or stream - banks where moving water is likely to wash out new vegetative plantings.

MATERIALS

A. Jute mat shall be cloth of a uniform plain weave of undyed and unbleached single jute yarn, 48 inches in width plus or minus 1 inch and weighing an average of 1.2 pounds per linear yard of cloth with a tolerance of plus or minus 5 percent, with approximately 78 warp ends per width of cloth and 41 weft ends per linear yard of cloth. The yarn shall be of a loosely twisted construction having an average twist of not less than 1.6 turns per inch and shall not vary in thickness by more than one half its normal diameter.

B. Excelsior mat shall be wood excelsior, 48 inches in width plus or minus 1 inch and weighing 0.8 pounds per square yard plus or minus 10 percent. The excelsoir material shall be covered with a netting to facilitate handling and to increase strength.

C. Glass fiber matting of bonded textile glass fibers with an average fiber diameter of 8 to 12 microns, 2 to 4 inch strands of fiber bonded with phenol formaldehyde resin. Mat shall be roll type, water permeable, minimum thickness 1/4 inch, maximum thickness 1/2 inch, density not less than 3 pounds per cubic foot.

D. Staples - staples for anchoring soil stabilizing materials shall be no. 11 gauge wire or heavier. Their length shall be 6 to 10 inches, with the longer staples used on loose, unstable soils.

*from USDA, Soil Conservation Service, College Park, Maryland. Standards and Specifications for Soil Erosion and Sediment Control in Developing Areas. July 1975.

INSTALLATION REQUIREMENTS

Site Preparation: After site has been shaped and graded to approved design, prepare a friable seedbed relatively free from clods and rocks more than 1-1/2 inches in diameter, and any foreign material that will prevent contact of the protective mat with the soil surface.

Planting: Lime, fertilize, and seed in accordance with seeding or other type of planting plan, except when using jute matting on a seeded area, apply approximately one-half the seed after laying the mat. The protective matting can be laid over sprigged areas where small grass plants have been planted. Where ground covers are to be planted, lay the protective matting first and then plant through the matting according to design of planting.

Erosion Stops: (For use on steep, highly erodible watercourses) Erosion stops are made of glass fiber strips, excelsior matting strips or tight-folded jute matting blanket or strips. They are placed in narrow trenches 6 to 12 inches deep across the channel and left flush with the soil surface. They are to cover the full cross-section of designed flow.

How Used: Under jute or excelsior matting.

Location:

1. Approximately 3 feet down channel from point of entry of a concentrated flow such as from culverts, tributary channels or diversions.
2. At points where change in gradient or course of channel occurs.
3. Spacing of erosion stops on long slopes will vary from 20 to 100 feet depending upon the erodibility of the soil and velocity and volume of flow.

Installation:

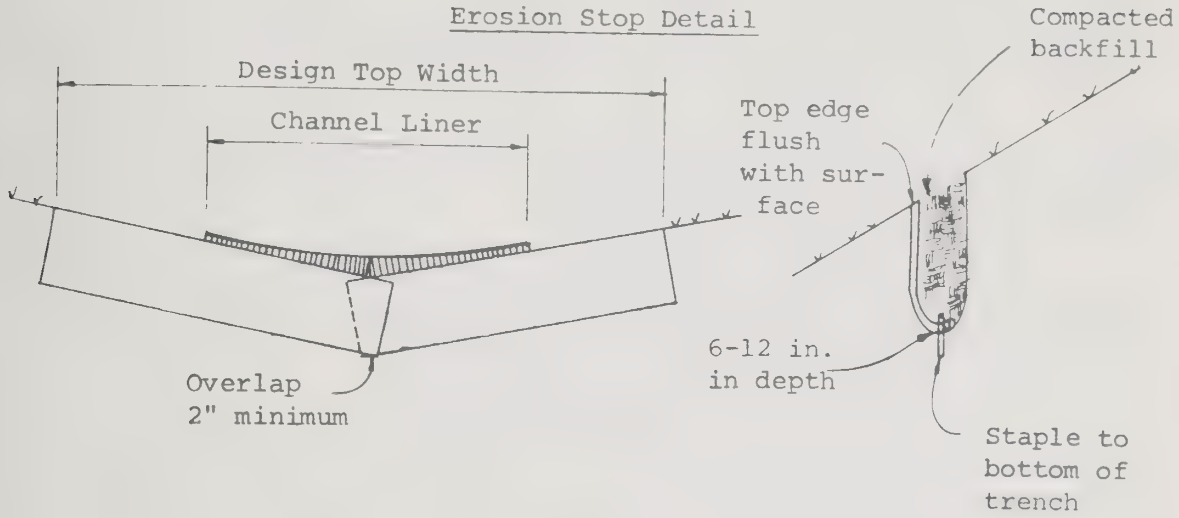
Erosion stops should extend beyond the channel liner to full design cross-section of the channel to check any rills that might form outside the channel lining.

The trench may be dug with a spade or a mechanical trencher making sure that the down slope face of the trench is flat; it should be uniform and perpendicular to line of flow to permit proper placement and stapling of the glass fiber matting.

The erosion stop should be deep enough to penetrate solid material or below level of rilling in sandy soils. In general, erosion stops will vary from 6 to 12 inches in depth.

The erosion stop mat should be wide enough to allow a minimum of 2 inch turnover at bottom of trench for stapling while maintaining the top edge flush with channel surface.

Tamp back fill firmly and to a uniform gradient of channel.



If seeding has been done prior to installation of erosion stops, reseed disturbed areas prior to placement of channel liner.

Laying Jute Matting: (If instructions have been followed, all needed erosion stops will have been installed, and the jute matting will be laid on a friable seedbed free from clods, rocks, roots, etc., that might cause bridging.)

Most channels will require multiple widths of jute matting, two widths being the most commonly used. Unroll matting starting at the upper end of the channel allowing a 4 inch overlap of mattings along center of channel.

Securing Jute Matting: Bury the top ends of jute matting in a narrow trench, minimum of 6 inch depth, similar to that used for erosion stops. Backfill trench and tamp firmly to conform to channel cross-section. Secure with a row of staples about 4 inches down slope from the trench. Spacing between staples is 6 inches.

Next, staple the 4 inch overlap in channel center using an 18 inch spacing between staples. Before stapling the outer edges of the matting, make sure the matting is smooth and in firm contact with the soil in its entirety, staples shall be placed 2 feet apart along the outer edge of matting.

Where one roll of jute matting ends and another begins, the end of the top strip shall overlap the upper end of the lower strip by 4 inches, shiplap fashion.

Where matting crosses erosion stops, reinforce with a double row of staples 6 inch spacing, staggered pattern on either side of erosion stop. Likewise, overlaps, joining the length of matting together and the discharge end of the matting liner should be similarly secured with 2 double rows of staples.

Laying and Securing Excelsior Matting: Same seedbed preparation as for jute matting with the exception that all seeding must be completed before laying excelsior matting.

Bury top ends of excelsior matting in a slit trench as described for jute matting. As the blankets are unrolled down slope, the matting must be on top with the wood fibers in contact with the soil. Butt snugly at ends and sides before stapling.

Using 2 foot spacing between staples, excelsior matting shall be secured with three rows for each strip, with one row along each edge and one alternating parallel rows down the center. The stapling over erosion stops, entrance and discharge ends of matting and butted end joints shall be the same as described for jute matting.

Final Check

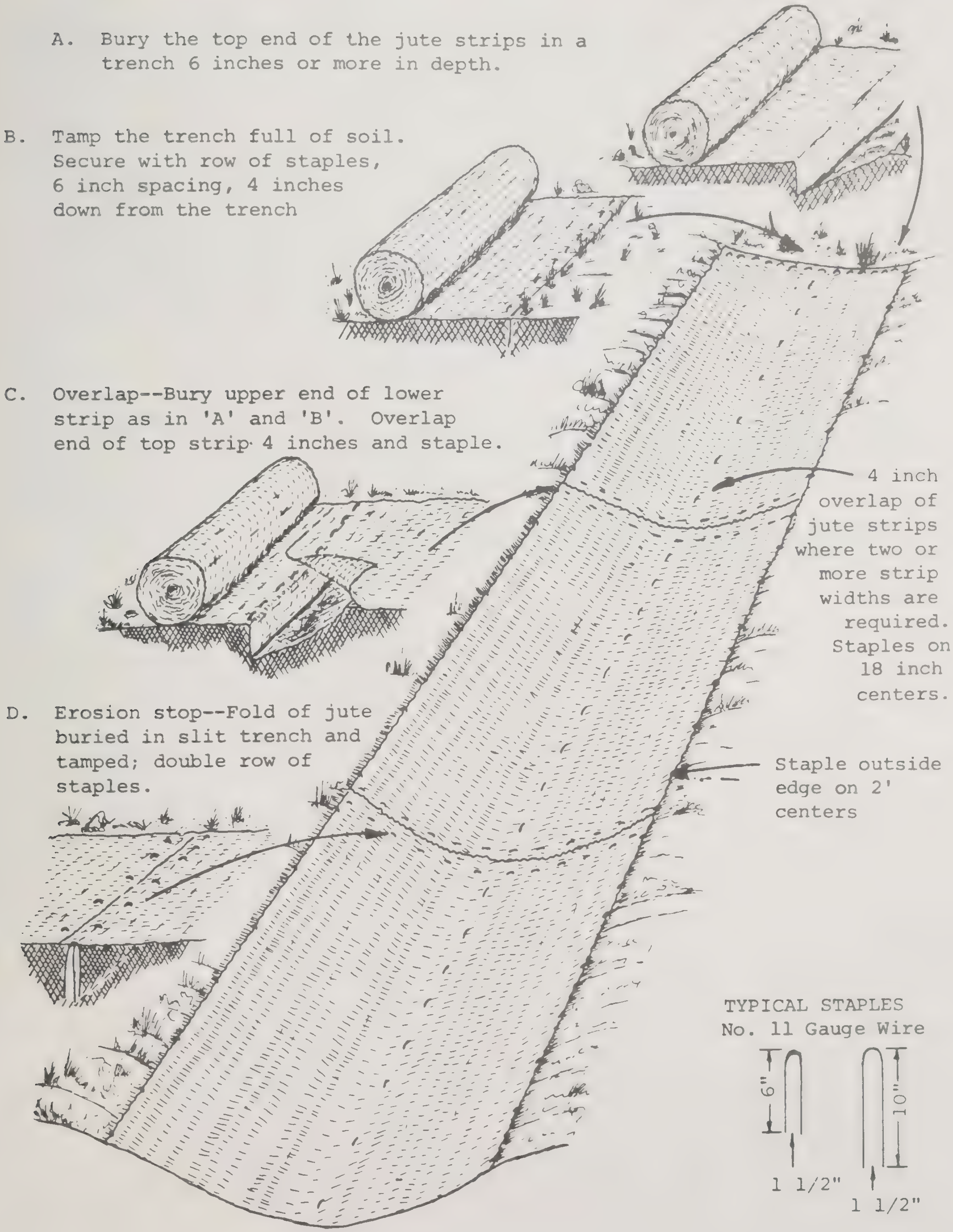
1. Make sure matting is uniformly in contact with the soil.

2. All lap joints are secure.

3. All staples are flush with the ground.

4. All disturbed areas seeded.

DETAIL FOR STABILIZING WATERWAYS WITH JUTE THATCHING



APPENDIX B*

SEDIMENT BASIN DESIGN

TEMPORARY SEDIMENT BASIN DESIGN DATA SHEET

Computed by____________ Date______
Checked by____________ Date______

Project________________________
Basin #________ Location____________________
Total Area draining to basin,_______ Acres.

BASIN VOLUME DESIGN

1. Min. required vol. = 67 cu. yds. x _____ ac. drainage = _____ cu. yds.
2. Vol. of basin = ______________________ = _____ cu. yds.
3. Excavate________ cu. yds. to obtain required capacity.
   Min. vol. before cleanout = 27 cu. yds. x _____ ac. drainage = ____ cu. yds.
   Elevation corresponding to scheduled time to clean out______________
   Distance below top of riser__________________

DESIGN OF SPILLWAYS

Runoff

4. Q_p=______________________ cfs (EFM, Ch. 2 or other appropriate method, attach runoff computation sheet).

Pipe Spillway (Q_{ps})

5. Min. pipe spillway capacity, Q_{ps} = 0.2 x _____ ac. drainage = ______ cfs.**
   Note: If there is no emergency spillway, then req'd. $Q_{ps} = Q_p$ = ____ cfs.***
6. H = _____ ft. Barrel length = ______ ft.
7. Barrel: Diam.____ inches; Q_{ps} = (Q)______ x (cor. fac.)_____ = ______ cfs.
8. Riser: Diam.____ inches; Length_____ ft.; h = _____ ft.
9. Trash Rack: Diam._____ inches; H= ______ inches.

Emergency Spillway Design

10. Emergency Spillway Flow, $Q_{es} = Q_p - Q_{ps}$ = _____ - ______ = ________ cfs.
11. Width______ ft. H_p_____ ft.
    Entrance channel slope____________________ %
    Exit channel slope_____________________ %

ANTI-SEEP COLLAR DESIGN (If Required)

12. y = _____ ft.; z = _____ :1; pipe slope = _____ %, L_s = _____ ft.
    Use _____ collars, ______ '- _____ " square; projection = _____ ft.

DESIGN ELEVATIONS

13. Riser Crest = ___________ Design High Water = __________
    Em. Spwy. Crest = ___________ Top of Dam = __________

*from USDA, Soil Conservation Service, College Park, Maryland. Standards and Specifications for Soil Erosion and Sediment Control in Developing Areas. July 1975

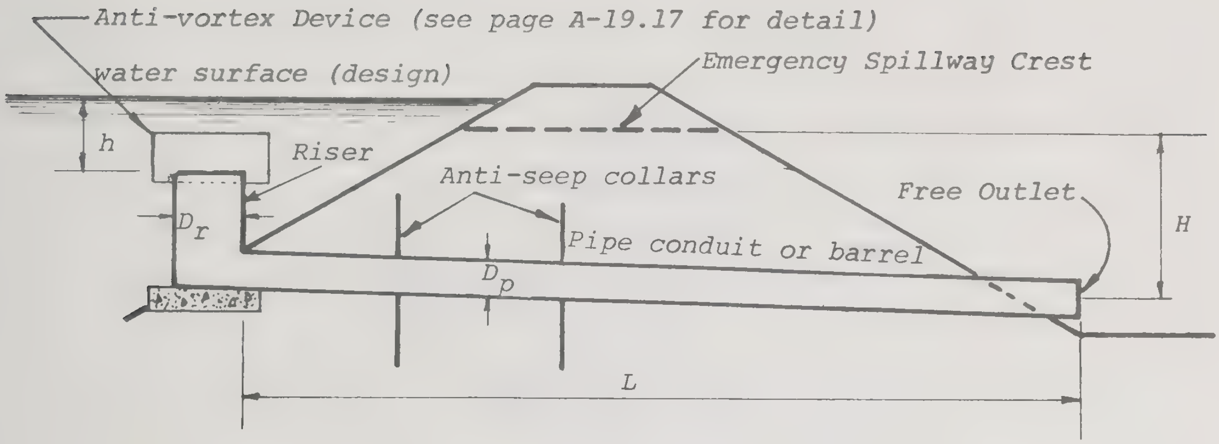
**In the Bay Area it is recommended that pipe spillway capacity Q, cfs, for the design storm be calculated by either the rational method or another locally approved method.

***In the Bay Area it is recommended that emergency spillways always be used.

TEMPORARY SEDIMENT BASIN DESIGN DATA SHEET
INSTRUCTIONS FOR USE OF FORM

1. Minimum required detention volume is 67 cubic yards per acre from each acre of drainage area. Values larger than 67 cubic yards per acre may be used for greater protection. Compute volume using entire drainage area although only part may be disturbed.
2. The volume of a naturally shaped (no excavation in basin) basin may be approximated by the formula $V = 0.4A\ d$, where V is in cubic feet, A is the surface area of the basin, in square feet, and d is the maximum depth of the basin, in feet. Volume may be computed from contour information or other suitable methods.
3. If volume of basin is not adequate for required storage, excavate to obtain the required volume.
4. The method described in the SCS Engineering field Manual, Chapter 2, is the preferred method for runoff computation. If rational method is used to compute runoff, obtain appropriate values for "I" and "C", depending on watershed conditions during development.
5. Required discharge from pipe spillway equals 0.2 cfs/ac. times total drainage area. (This is equivalent to a uniform runoff of 5" per 24 hours). The pipe shall be designed to carry Q_p if site conditions preclude installation of an emergency spillway to protect the structure.
6. Determine value of "H" from field conditions; "H" is interval between the centerline of the outlet pipe and the emergency spillway crest or if there is no emergency spillway, to the design high water.
7. See Pipe Spillway Design Charts, beginning on p. A-19.13.
8. See Riser Inflow Curves.
9. See Trash Rack and Anti-Vortex Device Design, p. A-19.17.
10. Compute Q_{es} by subtracting actual flow carried by the pipe spillway from the total inflow, Q_p.
11. Use appropriate tables to obtain values of H_p, bottom width, and actual Q_{es}. If no emergency spillway is to be used, so state, giving reason(s).
12. See Anti-Seep Collar Design, p. A-19.23, 24.
13. Fill in design elevations. The emergency spillway crest must be set no closer to riser crest than value of h which causes pipe spillway to carry the minimum required Q. Therefore, the elevation difference between spillways shall be equal to the value of h, or one foot, whichever is greater. Design high water is the elevation of the emergency spillway crest plus the value of H_p, or if there is no emergency spillway, it is the elevation of the riser crest plus h required to handle the 10-year storm. Minimum top of dam elevation requires 1.0 ft. of freeboard above design high water.

PIPE SPILLWAY DESIGN



H = Head on pipe spillway (pipe flow), ft. (centerline of outlet to emergency spillway crest or to design high water if no emergency spillway)

h = Head over riser crest, ft.

L = Length of pipe in ft.

D_p = Diameter of pipe conduit (barrel)

D_r = Diameter of riser

To use charts:

Enter chart, page A-19.15, or A-19.16 with H and required discharge.

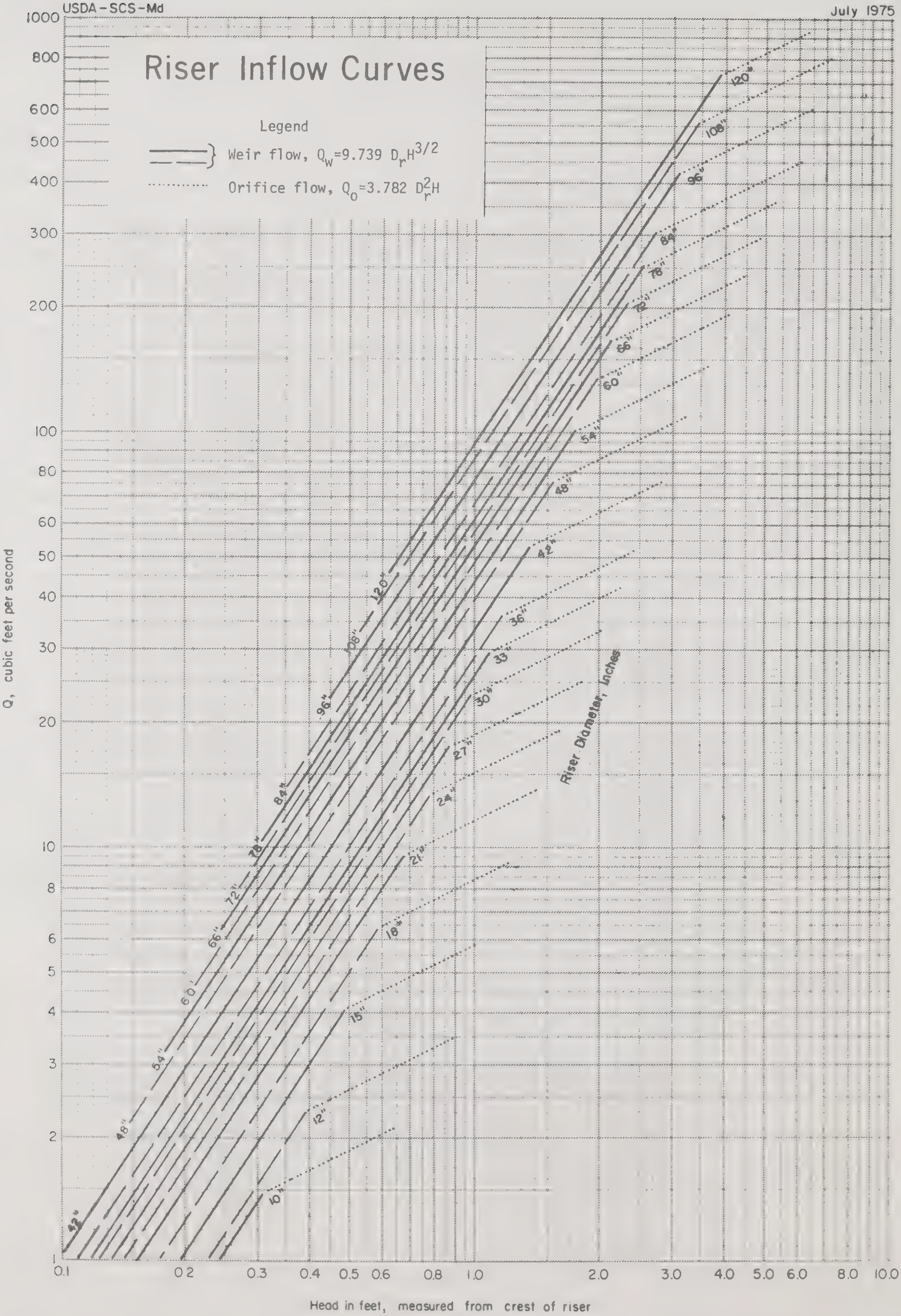
Find diameter of pipe conduit that provides equal or greater discharge.

Enter chart, page A-19.14, with actual pipe discharge. Read across to select smallest riser that provides discharge within weir flow portion of rating curve. Read down to find corresponding h required.

Example

Given: Q (required) = 5.8 cfs
L = 60'
H = 9' to centerline of pipe = Free outlet

Find: Pipe size, actual Q and size of riser.
Q of 12" pipe = 6.0 cfs x (correction factor) 1.07 = 6.4 cfs from the Pipe Flow Chart.
From Riser Inflow Curves, smallest riser = 18" (@ h = 0.6)


USDA-SCS-Md
July 1975
Riser Inflow Curves
Legend
Weir flow, $Q_W=9.739\ D_r H^{3/2}$
Orifice flow, $Q_O=3.782\ D_r^2 H$
Riser Diameter, Inches
Q, cubic feet per second
Head in feet, measured from crest of riser
1000
800
600
500
400
300
200
100
80
60
50
40
30
20
10
8
6
5
4
3
2
1
0.1
0.2
0.3
0.4
0.5
0.6
0.8
1.0
2.0
3.0
4.0
5.0
6.0
8.0
10.0
120"
108"
96"
84"
78"
72"
66"
60"
54"
48"
42"
36"
33"
30"
27"
24"
21"
18"
15"
12"
10"

PIPE FLOW CHART n = 0.013

FOR REINFORCED CONCRETE PIPE INLET $K_m = K_e + K_b = 0.65$ AND 70 FEET OF REINFORCED CONCRETE PIPE CONDUIT (full flow assumed)

Note correction factors for pipe lengths other than 70 feet

diameter of pipe in inches

H, in feet	12"	15"	18"	21"	24"	30"	36"	42"	48"	54"	60"	66"	72"	78"	84"	90"	96"	102"
1	3.22	5.44	8.29	11.8	15.9	26.0	38.6	53.8	71.4	91.5	114	139	167	197	229	264	302	342
2	4.55	7.69	11.7	16.7	22.5	36.8	54.6	76.0	101	129	161	197	236	278	324	374	427	483
3	5.57	9.42	14.4	20.4	27.5	45.0	66.9	93.1	124	159	198	241	289	341	397	458	523	592
4	6.43	10.9	16.6	23.5	31.8	52.0	77.3	108	143	183	228	278	334	394	459	529	604	683
5	7.19	12.2	18.5	26.3	35.5	58.1	86.4	120	160	205	255	311	373	440	513	591	675	764
6	7.88	13.3	20.3	28.8	38.9	63.7	94.6	132	175	224	280	341	409	482	562	647	739	837
7	8.51	14.4	21.9	31.1	42.0	68.8	102	142	189	242	302	368	441	521	607	699	798	904
8	9.10	15.4	23.5	33.3	44.9	73.5	109	152	202	259	323	394	472	557	685	748	854	966
9	9.65	16.3	24.9	35.3	47.7	78.0	116	161	214	275	342	418	500	590	688	793	905	1025
10	10.2	17.2	26.2	37.2	50.2	82.2	122	170	226	289	361	440	527	622	725	836	954	1080
11	10.7	18.0	27.5	39.0	52.7	86.2	128	178	237	304	379	462	553	653	761	877	1001	1133
12	11.1	18.9	28.7	40.8	55.0	90.1	134	186	247	317	395	482	578	682	794	916	1045	1184
13	11.6	19.6	29.9	42.4	57.3	93.7	139	194	257	330	411	502	601	710	827	953	1088	1232
14	12.0	20.4	31.0	44.1	59.4	97.3	145	201	267	342	427	521	624	736	858	989	1129	1278
15	12.5	21.1	32.1	45.6	61.5	101	150	208	277	354	442	539	646	762	888	1024	1169	1323
16	12.9	21.8	33.2	47.1	63.5	104	155	215	286	366	457	557	667	787	917	1057	1207	1367
17	13.3	22.4	34.2	48.5	65.5	107	159	222	294	377	471	574	688	812	946	1090	1244	1409
18	13.7	23.1	35.2	49.9	67.4	110	164	228	303	388	484	591	708	835	973	1121	1280	1450
19	14.0	23.7	36.1	51.3	69.2	113	168	234	311	399	497	607	727	858	1000	1152	1315	1489
20	14.4	24.3	37.1	52.6	71.0	116	173	240	319	409	510	623	746	880	1026	1182	1350	1528
21	14.7	24.9	38.0	53.9	72.8	119	177	246	327	419	523	638	764	902	1051	1211	1383	1566
22	15.1	25.5	38.9	55.2	74.5	122	181	252	335	429	535	653	782	923	1076	1240	1415	1603
23	15.4	26.1	39.8	56.5	76.2	125	186	258	342	439	547	668	800	944	1100	1268	1447	1639
24	15.8	26.7	40.6	57.7	77.8	127	189	263	350	448	559	682	817	964	1123	1295	1478	1674
25	16.1	27.2	41.5	58.9	79.4	130	193	269	357	458	571	696	834	984	1147	1322	1509	1708
26	16.4	27.7	42.3	60.0	81.0	133	197	274	364	467	582	710	850	1004	1169	1348	1539	1742
27	16.7	28.3	43.1	61.2	82.5	135	201	279	371	476	593	723	867	1023	1192	1373	1568	1775
28	17.0	28.8	43.9	62.3	84.1	138	204	285	378	484	604	737	883	1041	1214	1399	1597	1808
29	17.3	29.3	44.7	63.4	85.5	140	208	290	384	493	615	750	898	1060	1235	1423	1625	1840
30	17.6	29.8	45.4	64.5	87.0	142	212	294	391	501	625	763	913	1078	1256	1448	1653	1871
L, in feet	Correction Factors For Other Pipe Lengths																	
20	1.30	1.24	1.21	1.18	1.15	1.12	1.10	1.08	1.07	1.06	1.05	1.05	1.04	1.04	1.03	1.03	1.03	1.03
30	1.22	1.18	1.15	1.13	1.12	1.09	1.08	1.06	1.05	1.05	1.04	1.04	1.03	1.03	1.03	1.02	1.02	1.02
40	1.15	1.13	1.11	1.10	1.08	1.07	1.05	1.05	1.04	1.03	1.03	1.03	1.02	1.02	1.02	1.02	1.02	1.02
50	1.09	1.08	1.07	1.06	1.05	1.04	1.04	1.03	1.03	1.02	1.02	1.02	1.02	1.01	1.01	1.01	1.01	1.01
60	1.04	1.04	1.03	1.03	1.03	1.02	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
70	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
80	.96	.97	.97	.97	.98	.98	.98	.99	.99	.99	.99	.99	.99	.99	.99	.99	.99	.99
90	.93	.94	.94	.95	.95	.96	.97	.97	.98	.98	.98	.98	.98	.99	.99	.99	.99	.99
100	.90	.91	.92	.93	.93	.95	.95	.96	.97	.97	.97	.98	.98	.98	.98	.98	.98	.99
120	.84	.86	.87	.89	.90	.91	.93	.94	.94	.95	.96	.96	.96	.97	.97	.97	.97	.98
140	.80	.82	.83	.85	.86	.88	.90	.91	.92	.93	.94	.94	.95	.95	.96	.96	.96	.97
160	.76	.78	.80	.82	.83	.86	.88	.89	.90	.91	.92	.93	.94	.94	.95	.95	.95	.96

PIPE FLOW CHART n = 0.025

FOR CORRUGATED METAL PIPE INLET $K_m = K_e + K_b = 1.0$ AND 70 FEET OF CORRUGATED METAL PIPE CONDUIT (full flow assumed)

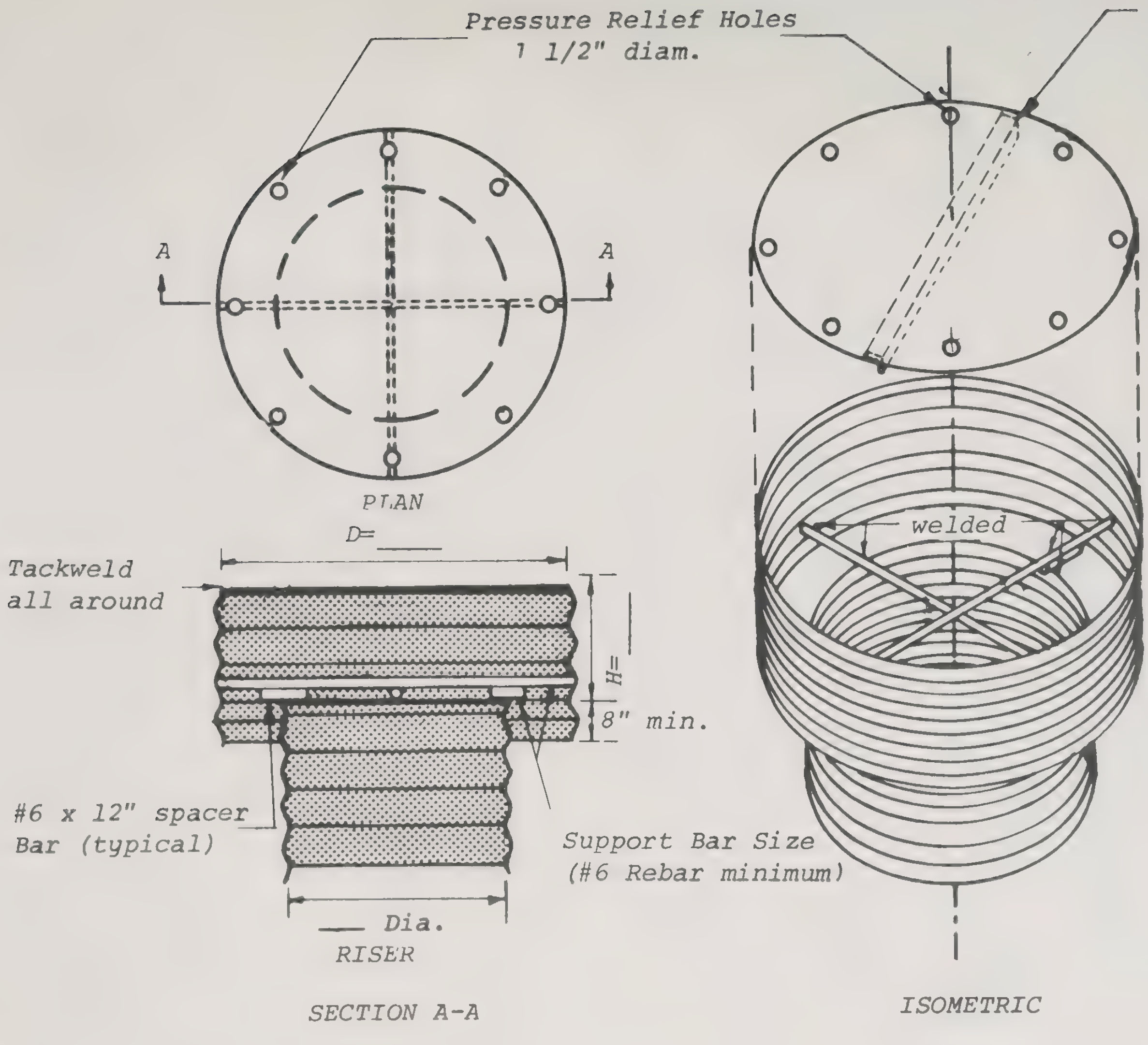
Note correction factors for pipe lengths other than 70 feet

diameter of pipe in inches

H, in feet	6"	8"	10"	12"	15"	18"	21"	24"	30"	36"	42"	48"	54"	60"	66"	72"	78"	84"	90"	96"	102"
1	0.33	0.70	1.25	1.98	3.48	5.47	7.99	11.0	18.8	28.8	41.1	55.7	72.6	91.8	113	137	163	191	222	255	290
2	0.47	0.99	1.76	2.80	4.92	7.74	11.3	15.6	26.6	40.8	58.2	78.8	103	130	160	194	231	271	314	360	410
3	0.58	1.22	2.16	3.43	6.02	9.48	13.8	19.1	32.6	49.9	71.2	96.5	126	159	196	237	282	331	384	441	502
4	0.67	1.40	2.49	3.97	6.96	10.9	16.0	22.1	37.6	57.7	82.3	111	145	184	226	274	326	383	444	510	580
5	0.74	1.57	2.79	4.43	7.78	12.2	17.9	24.7	42.1	64.5	92.0	125	162	205	253	306	365	428	496	570	648
6	0.82	1.72	3.05	4.86	8.52	13.4	19.6	27.0	46.1	70.6	101	136	178	225	277	336	399	469	544	624	710
7	0.88	1.86	3.30	5.25	9.20	14.5	21.1	29.2	49.8	76.3	109	147	192	243	300	362	431	506	587	674	767
8	0.94	1.99	3.53	5.61	9.84	15.5	22.6	31.2	53.2	81.5	116	158	205	260	320	388	461	541	628	721	820
9	1.00	2.11	3.74	5.95	10.4	16.4	24.0	33.1	56.4	86.5	123	167	218	275	340	411	489	574	666	764	870
10	1.05	2.22	3.94	6.27	11.0	17.3	25.3	34.9	59.5	91.2	130	176	230	290	358	433	516	605	702	806	917
11	1.10	2.33	4.13	6.58	11.5	18.2	26.5	36.6	62.4	95.6	136	185	241	304	376	454	541	635	736	845	962
12	1.15	2.43	4.32	6.87	12.1	19.0	27.7	38.2	65.2	99.9	142	193	252	318	392	475	565	663	769	883	1004
13	1.20	2.53	4.49	7.15	12.6	19.7	28.8	39.8	67.8	104	148	201	262	331	408	494	588	690	800	919	1045
14	1.25	2.63	4.66	7.42	13.0	20.5	29.9	41.3	70.4	108	154	208	272	343	424	513	610	716	830	953	1085
15	1.29	2.72	4.83	7.68	13.5	21.2	30.9	42.8	72.8	112	159	216	281	355	439	531	631	741	860	987	1123
16	1.33	2.81	4.99	7.93	13.9	21.9	32.0	44.2	75.2	115	165	223	290	367	453	548	652	765	888	1019	1160
17	1.37	2.90	5.14	8.18	14.3	22.6	32.9	45.5	77.5	119	170	230	229	378	467	565	672	789	915	1051	1195
18	1.41	2.98	5.29	8.41	14.8	23.2	33.9	46.8	79.8	120	174	236	308	389	480	581	692	812	942	1081	1230
19	1.45	3.06	5.43	8.64	15.2	23.9	34.8	48.1	82.0	126	179	243	316	400	494	597	711	834	967	1111	1264
20	1.49	3.14	5.57	8.87	15.6	24.5	35.7	49.4	84.1	129	184	249	325	410	506	613	729	856	993	1139	1297
21	1.53	3.22	5.71	9.09	15.9	25.1	36.6	50.6	86.2	132	188	255	333	421	519	628	747	877	1017	1168	1329
22	1.56	3.29	5.85	9.30	16.3	25.7	37.5	51.8	88.2	135	193	261	341	430	531	643	765	898	1041	1195	1360
23	1.60	3.37	5.98	9.51	16.7	26.2	38.3	53.0	90.2	138	197	267	348	440	543	657	782	918	1064	1222	1390
24	1.63	3.44	6.11	9.72	17.0	26.8	39.1	54.1	92.1	141	201	273	356	450	555	671	799	937	1087	1248	1420
25	1.66	3.51	6.23	9.92	17.4	27.4	39.9	55.2	94.0	144	206	279	363	459	566	685	815	957	1110	1274	1450
26	1.70	3.58	6.36	10.1	17.7	27.9	40.7	56.3	95.9	147	210	284	370	468	577	699	831	976	1132	1299	1478
27	1.73	3.65	6.48	10.3	18.1	28.4	41.5	57.4	97.7	150	214	290	377	477	588	712	847	994	1153	1324	1507
28	1.76	3.72	6.60	10.5	18.4	29.0	42.3	58.4	99.5	153	218	295	384	486	599	725	863	1013	1174	1348	1534
29	1.79	3.78	6.71	10.7	18.7	29.5	43.0	59.5	101	155	221	300	391	494	610	738	878	1030	1195	1372	1561
30	1.82	3.85	6.83	10.9	19.1	30.0	43.7	60.5	103	158	225	305	398	503	620	750	893	1048	1216	1396	1588

Correction Factors For Other Pipe Lengths

L, in feet	6"	8"	10"	12"	15"	18"	21"	24"	30"	36"	42"	48"	54"	60"	66"	72"	78"	84"	90"	96"	102"
20	1.69	1.63	1.58	1.53	1.47	1.42	1.37	1.34	1.28	1.24	1.20	1.18	1.16	1.14	1.13	1.11	1.10	1.10	1.09	1.08	1.08
30	1.44	1.41	1.39	1.36	1.32	1.29	1.27	1.24	1.21	1.18	1.15	1.13	1.12	1.11	1.10	1.09	1.08	1.07	1.07	1.06	1.06
40	1.28	1.27	1.25	1.23	1.21	1.20	1.18	1.17	1.14	1.12	1.11	1.10	1.09	1.08	1.07	1.06	1.06	1.05	1.05	1.05	1.04
50	1.16	1.16	1.15	1.14	1.13	1.12	1.11	1.10	1.09	1.08	1.07	1.06	1.06	1.05	1.05	1.04	1.04	1.04	1.03	1.03	1.03
60	1.07	1.07	1.07	1.06	1.06	1.05	1.05	1.05	1.04	1.04	1.03	1.03	1.03	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.01
70	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
80	.94	.94	.95	.95	.95	.95	.96	.96	.96	.97	.97	.97	.98	.98	.98	.98	.98	.98	.99	.99	.99
90	.89	.89	.90	.90	.91	.91	.92	.92	.93	.94	.94	.95	.95	.96	.96	.96	.97	.97	.97	.97	.94
100	.85	.85	.86	.86	.87	.88	.89	.89	.90	.91	.92	.93	.93	.94	.94	.95	.95	.95	.96	.96	.94
120	.78	.79	.79	.90	.81	.82	.83	.83	.85	.86	.87	.89	.89	.90	.91	.89	.92	.93	.93	.94	.92
140	.72	.73	.74	.75	.76	.77	.78	.79	.81	.82	.84	.85	.86	.87	.88	.86	.89	.90	.91	.91	.90
160	.68	.69	.69	.70	.71	.73	.74	.75	.77	.79	.80	.82	.83	.84	.85	.92	.87	.88	.89	.89	



Top stiffener (if required) is ____x____x____ angle welded to top and oriented perpendicular to corrugations.

Top is ____ gage corrugated metal or 1/8" steel plate. Pressure relief holes may be ommitted,if ends of corrugations are left fully open when corrugated top is welded to cylinder.

Cylinder is ____ gage corrugated metal pipe or fabricated from 1/8" steel plate.

Notes:
1) The cylinder must be firmly fastened to the top of the riser.
2) Support bars are welded to the top of the riser or attached by straps bolted to top of riser.

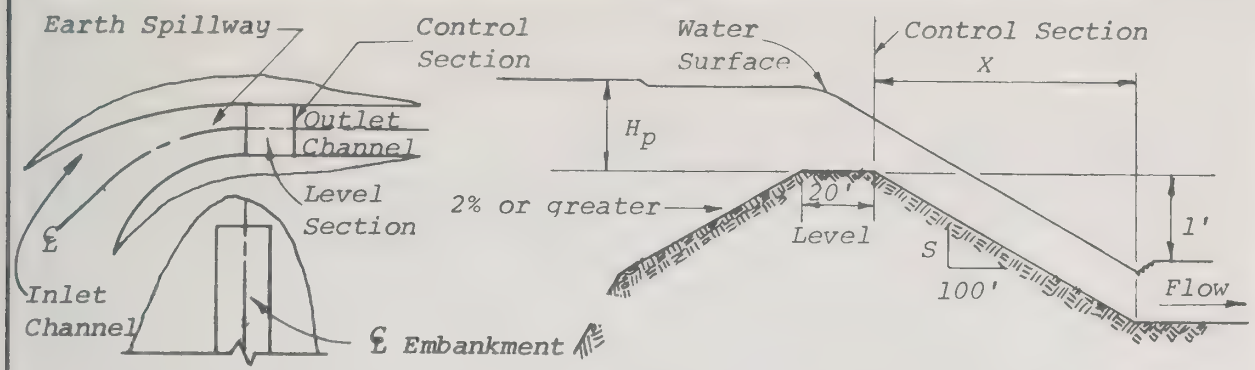
CONCENTRIC TRASH RACK AND ANTI-VORTEX DEVICE
(not to scale)

CONCENTRIC TRASH RACK AND ANTI-VORTEX DEVICE

DESIGN TABLE

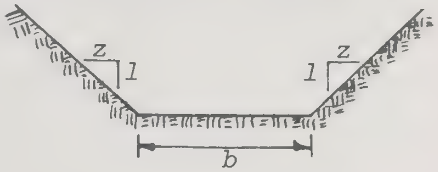
Riser Diam., in.	Cylinder Diam. in.	Cylinder Thick., gage	H, in.	Minimum Size Support Bar	Minimum Top Thickness	Minimum Top Stiffener
12	18	16	6	#6 Rebar	16 ga.	-
15	21	16	7	"	"	-
18	27	16	8	"	"	-
21	30	16	11	"	"	-
24	36	16	13	"	14 ga.	-
27	42	16	15	"	14 ga.	-
36	54	14	17	#8 Rebar	12 ga.	-
42	60	14	19	"	"	-
48	72	12	21	1-1/4" pipe or 1-1/4x1-1/4x1/4 angle	10 ga.	-
54	78	12	25	"	"	-
60	90	12	29	1-1/2" pipe or 1-1/2x1-1/2x1/4 angle	8 ga.	-
66	96	10	33	2" pipe or 2x2x3/16 angle	8 ga., w/stiffener	2x2x1/4 angle
72	102	10	36	"	"	2-1/2x2-1/2x 1/4 angle
78	114	10	39	2-1/2" pipe or 2x2x1/4 angle	"	"
84	120	10	42	2-1/2" pipe or 2-1/2x2-1/2x1/4 angle	"	2-1/2x2-1/2x 5/16 angle

Note: The criteria for sizing the cylinder is that the area between the inside of the cylinder and the outside of the riser is equal to or greater than the area inside the riser. Therefore, the above table is invalid for use with concrete pipe risers.



PLAN OF EARTH SPILLWAY

PROFILE ALONG ℄ OF EARTH SPILLWAY



CROSS SECTION OF EARTH SPILLWAY AT CONTROL SECTION

LEGEND

n = Manning's Coefficient of Roughness.
H_p = Difference in Elevation between Crest of Earth Spillway at the Control Section and Water Surface in Reservoir, in feet.
b = Bottom Width of Earth Spillway at the Control Section, in feet.
Q = Total Discharge, in cfs.
V = Velocity, in feet per second, that will exist in Channel below Control Section, at Design Q, if constructed to slope (S) that is shown.
S = Flattest Slope (S), in %, allowable for Channel below Control Section.
X = Minimum Length of Channel below Control Section, in feet.
z = Side Slope Ratio.

NOTES:

1) For a given H_p a decrease in the exit slope from S as given in the table decreases spillway discharge but increasing the exit slope from S does not increase discharge. If an exit slope (S_e) steeper than S is used, then velocity (V_e) in the exit channel will increase according to the following relationship:

$$V_e = V\left(\frac{S_e}{S}\right)^{0.3}$$

2) Data to right of heavy vertical lines on drawings should be used with caution, as the resulting sections will be either poorly proportioned or have velocities in excess of 6 ft/sec.

U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE College Park, Md.	DESIGN DATA FOR EARTH SPILLWAYS	Ref: Engineering Field Manual

DESIGN DATA FOR EARTH SPILLWAYS

SIDE SLOPE 2:1
VEGETATED n=0.040

STAGE (Hp) IN FEET	SPILLWAY VARIABLES	BOTTOM WIDTH (b) IN FEET																
		8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
0.5	Q	6	7	8	10	11	13	14	15	17	18	20	21	22	24	25	27	28
	V	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
	S	3.9	3.9	3.9	3.9	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
	X	32	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
0.6	Q	8	10	12	14	16	18	20	22	24	26	28	30	32	34	35	37	39
	V	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
	S	3.7	3.7	3.7	3.7	3.6	3.7	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
	X	36	36	36	36	36	36	37	37	37	37	37	37	37	37	37	37	37
0.7	Q	11	13	16	18	20	23	25	28	30	33	35	38	41	43	44	46	48
	V	3.2	3.2	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
	S	3.5	3.5	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
	X	39	40	40	40	41	41	41	41	41	41	41	41	41	41	41	41	41
0.8	Q	13	16	19	22	26	29	32	35	38	42	45	46	48	51	54	57	60
	V	3.5	3.5	3.5	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
	S	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
	X	44	44	44	44	45	45	45	45	45	45	45	45	45	45	45	45	45
0.9	Q	17	20	24	28	32	35	39	43	47	51	53	57	60	64	68	71	75
	V	3.7	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
	S	3.2	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
	X	47	47	48	48	48	48	48	48	48	48	49	49	49	49	49	49	49
1.0	Q	20	24	29	33	38	42	47	51	56	61	63	68	72	77	81	86	90
	V	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
	S	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
	X	51	51	51	51	52	52	52	52	52	52	52	52	52	52	52	52	52
1.1	Q	23	28	34	39	44	49	54	60	65	70	74	79	84	89	95	100	105
	V	4.2	4.2	4.2	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
	S	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
	X	55	55	55	55	55	55	55	56	56	56	56	56	56	56	56	56	56
1.2	Q	28	33	40	45	51	58	64	69	76	80	86	92	98	104	110	116	122
	V	4.4	4.4	4.4	4.4	4.4	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
	S	2.9	2.9	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
	X	58	58	59	59	59	59	59	59	60	60	60	60	60	60	60	60	60
1.3	Q	32	38	46	53	58	65	73	80	86	91	99	106	112	119	125	133	140
	V	4.5	4.6	4.6	4.6	4.6	4.6	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7
	S	2.8	2.8	2.8	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
	X	62	62	62	63	63	63	63	63	63	63	63	64	64	64	64	64	64
1.4	Q	37	44	51	59	66	74	82	90	96	103	111	119	127	134	142	150	158
	V	4.7	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9
	S	2.8	2.7	2.7	2.7	2.7	2.7	2.7	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6
	X	65	66	66	66	66	67	67	67	67	67	67	68	68	68	68	68	69
1.5	Q	41	50	58	66	75	85	92	101	108	116	125	133	142	150	160	169	178
	V	4.8	4.9	4.9	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.1	5.1	5.1
	S	2.7	2.7	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.5	2.5	2.5
	X	69	69	70	70	71	71	71	71	71	71	71	72	72	72	72	72	72
1.6	Q	46	56	65	75	84	94	104	112	122	132	142	149	158	168	178	187	197
	V	5.0	5.1	5.1	5.1	5.1	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2
	S	2.6	2.6	2.6	2.6	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
	X	72	74	74	75	75	76	76	76	76	76	76	76	76	76	76	76	76
1.7	Q	52	62	72	83	94	105	115	126	135	145	156	167	175	187	196	206	217
	V	5.2	5.2	5.2	5.3	5.3	5.3	5.3	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4
	S	2.6	2.6	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
	X	76	78	79	80	80	80	80	80	80	80	80	80	80	80	80	80	80
1.8	Q	58	69	81	93	104	116	127	138	150	160	171	182	194	204	214	226	233
	V	5.3	5.4	5.4	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.6	5.6	5.6	5.6	5.6	5.6
	S	2.5	2.5	2.5	2.5	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
	X	80	82	83	84	84	84	84	84	84	84	84	84	84	84	84	84	84
1.9	Q	64	76	88	102	114	127	140	152	164	175	188	201	213	225	235	248	260
	V	5.5	5.5	5.5	5.6	5.6	5.6	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7
	S	2.5	2.5	2.5	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
	X	84	85	86	87	88	88	88	88	88	88	88	88	88	88	88	88	88
2.0	Q	71	83	97	111	125	138	153	164	178	193	204	218	232	245	256	269	283
	V	5.6	5.7	5.7	5.7	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.9	5.9	5.9	5.9	5.9	5.9
	S	2.5	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
	X	88	90	91	91	91	91	92	92	92	92	92	92	92	92	92	92	92
2.1	Q	77	91	107	122	135	149	162	177	192	207	220	234	250	267	276	291	305
	V	5.7	5.8	5.9	5.9	5.9	5.9	5.9	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
	S	2.4	2.4	2.4	2.4	2.4	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
	X	92	93	95	95	95	95	95	95	95	96	96	96	96	96	96	96	96
2.2	Q	84	100	116	131	146	163	177	194	210	224	238	253	269	288	301	314	330
	V	5.9	5.9	6.0	6.0	6.0	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.2	6.2	6.2	6.2
	S	2.4	2.4	2.4	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
	X	96	98	99	99	99	99	99	100	100	100	100	100	100	100	100	100	100
2.3	Q	90	108	124	140	158	175	193	208	226	243	258	275	292	306	323	341	354
	V	6.0	6.1	6.1	6.1	6.2	6.2	6.2	6.2	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3
	S	2.4	2.4	2.3	2.3	2.3	2.3	2.3	2.3	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
	X	100	102	102	103	103	103	104	104	104	105	105	105	105	105	105	105	105
2.4	Q	99	116	136	152	170	189	206	224	241	260	275	294	312	327	346	364	378
	V	6.1	6.2	6.2	6.3	6.3	6.3	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4
	S	2.3	2.3	2.3	2.3	2.3	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
	X	105	105	106	107	107	108	108	108	108	109	109	109	109	109	109	109	109

REFERENCE

Engineering Field Manual

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING & WATERSHED PLANNING UNIT
UPPER DARBY, PENNSYLVANIA

RTSC-NE-ENG.
1110
SHEET 4 OF 11

ANTI-SEEP COLLAR DESIGN

This procedure provides the anti-seep collar dimensions for only temporary sediment basins to increase the seepage length by 10% for various pipe slopes, embankment slopes and riser heights. This does not apply to permanent structures, which must have an increase of 15% in the seepage length.

The first step in designing anti-seep collars is to determine the length of pipe within the saturated zone of the embankment. This can be done graphically or by the following equation, assuming that the upstream slope of the embankment intersects the invert of the pipe at its upstream end. (See embankment-invert intersection on the drawing below:

$$L_s = y\ (z + 4)\ \left[1 + \frac{\text{pipe slope}}{0.25\text{-pipe slope}}\right]$$

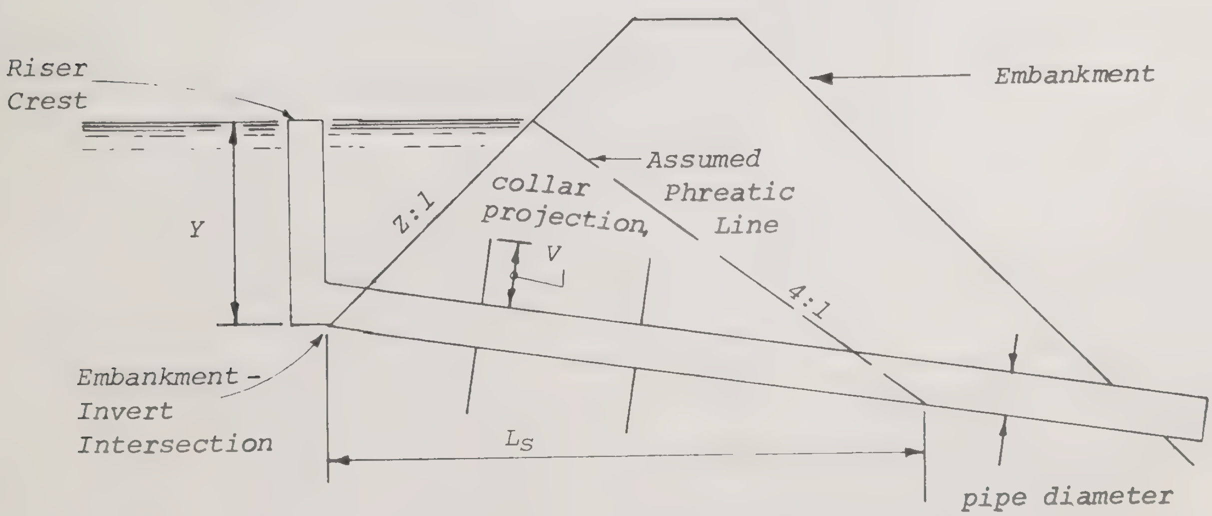
where: L_s = length of pipe in the saturated zone (ft.)

y = distance in feet from upstream invert of pipe to highest normal water level expected to occur during the life of the structure, usually the top of the riser.

z = slope of upstream embankment as a ratio of z ft. horizontal to one ft. vertical.

pipe slope = slope of pipe in feet per foot.

This procedure is based on the approximation of the phreatic line as shown in the drawing below:



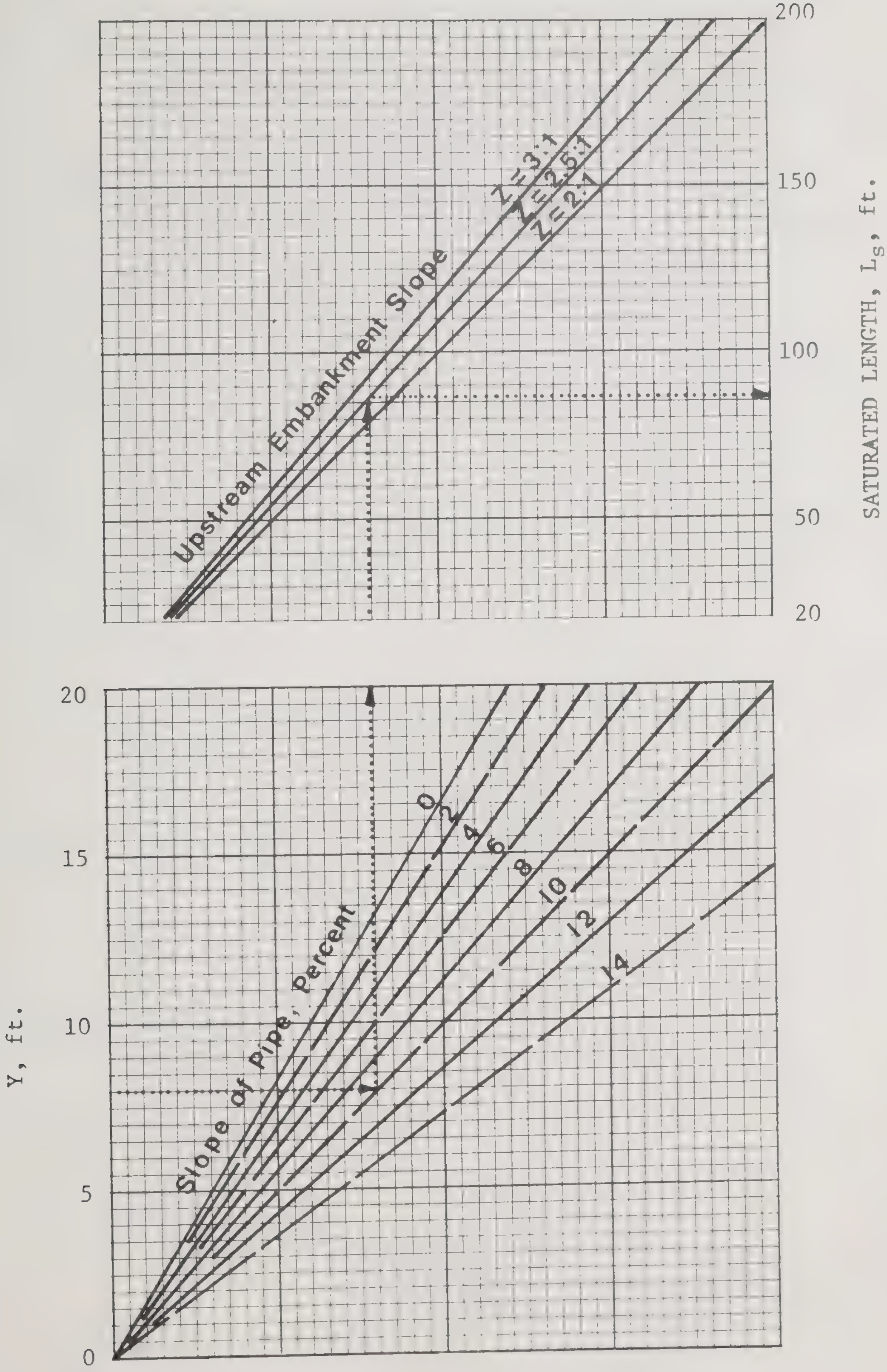
The solution to this equation is given by the chart on the following page for a range of sediment basin configurations. The anti-seep collar size can then be found from the chart on the succeeding page.

Example - Given: y = 8 ft., embankment slope = 2.5:1, pipe slope = 10%, pipe diameter = 36".

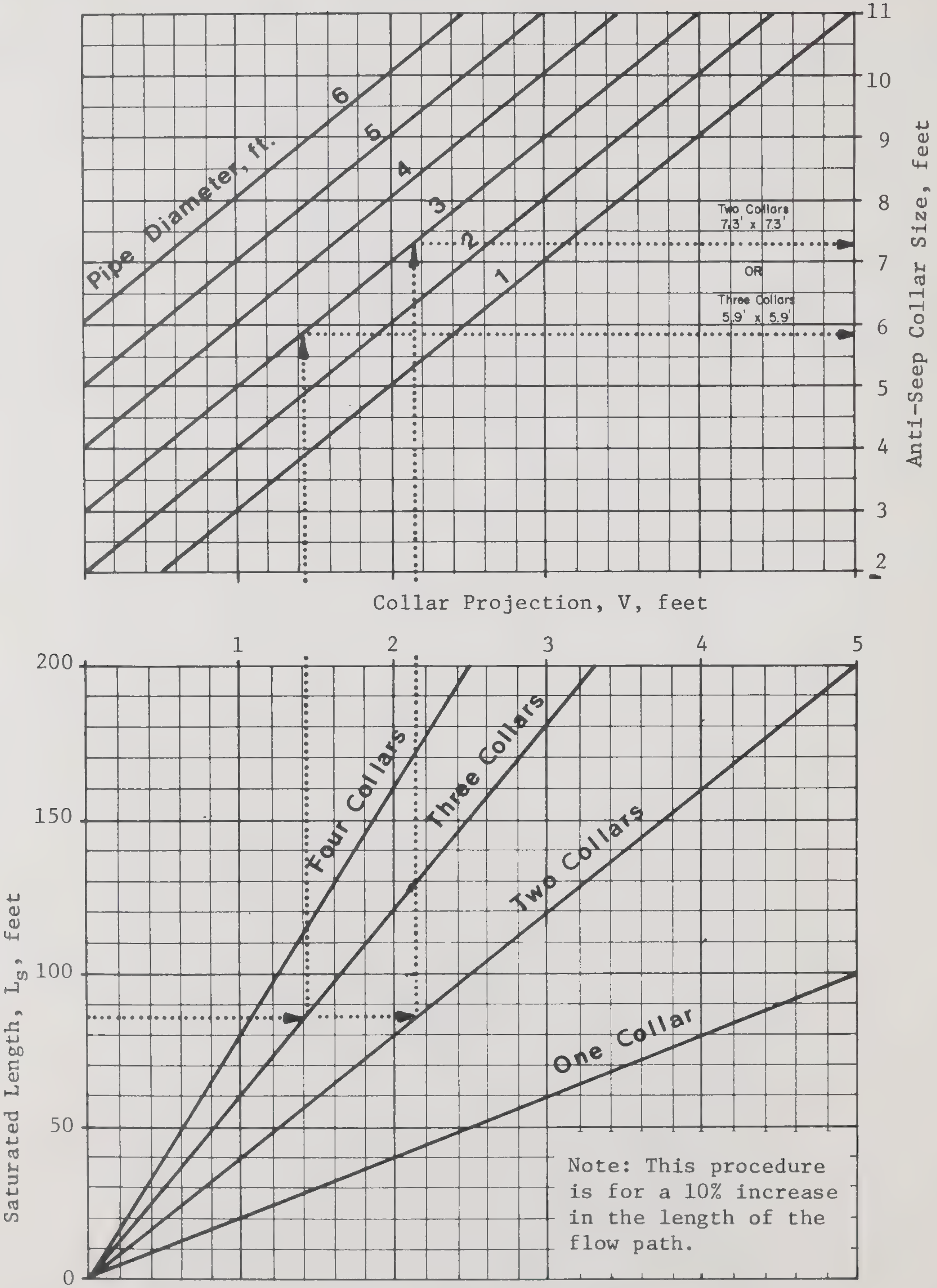
Find: number and size of anti-seep collars.

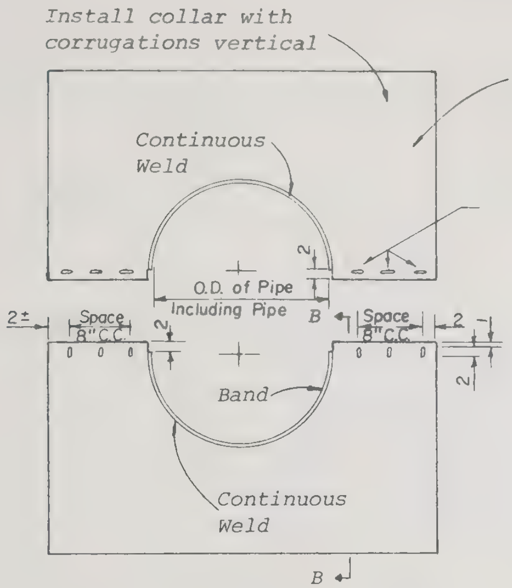
On page A-19.23 of this Appendix, read saturated length, L_s = 87 ft. On page A-19.24 for two collars, the size would be 7.3', and for three collars, 5.9'. Select the two collars since they would be less expensive and easier to install. Collar sizes should be given in feet and inches, therefore, use 2 collars 7'-4" x 7'-4". From page A-19.24 the projection is 2.15'. Therefore, maximum collar spacing is (14) (2.15) = 30.1 ft.

PIPE LENGTH IN SATURATED ZONE

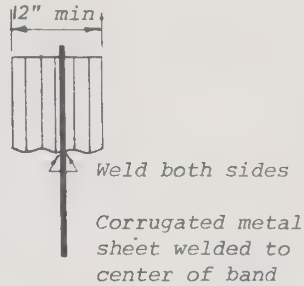


ANTI-SEEP COLLAR DESIGN





ELEVATION OF UNASSEMBLED COLLAR



SECTION B-B

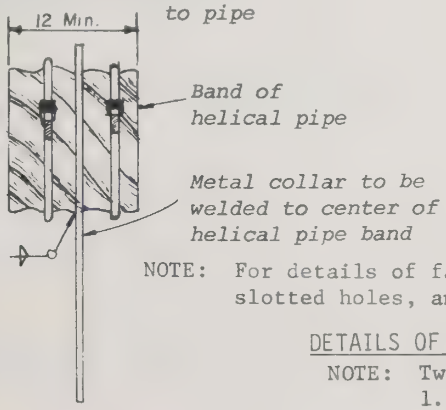
NOTES FOR COLLARS:

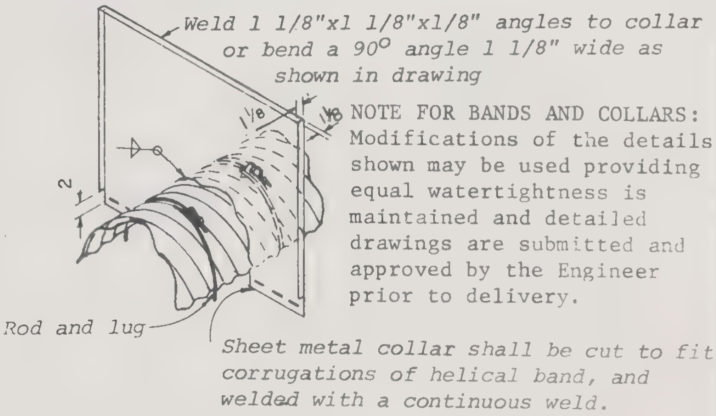
1. All materials to be in accordance with construction and construction material specifications.
2. When specified on the plans, coating of collars shall be in accordance with construction and construction material specifications.
3. Unassembled collars shall be marked by painting or tagging to identify matching pairs.
4. The lap between the two half sections and between the pipe and connecting band shall be caulked with asphalt mastic at time of installation.
5. Each collar shall be furnished with two 1/2" diameter rods with standard tank lugs for connecting collars to pipe.

DETAILS OF CORRUGATED METAL ANTI-SEEP COLLAR

Size and spacing of slotted openings shall be the same as shown for CM collar

Use rods and lugs to clamp bands securely to pipe





NOTE FOR BANDS AND COLLARS: Modifications of the details shown may be used providing equal watertightness is maintained and detailed drawings are submitted and approved by the Engineer prior to delivery.

ISOMETRIC VIEW

NOTE: For details of fabrication dimensions, minimum gages, slotted holes, and notes, see detail above.

DETAILS OF HELICAL PIPE ANTI-SEEP COLLAR

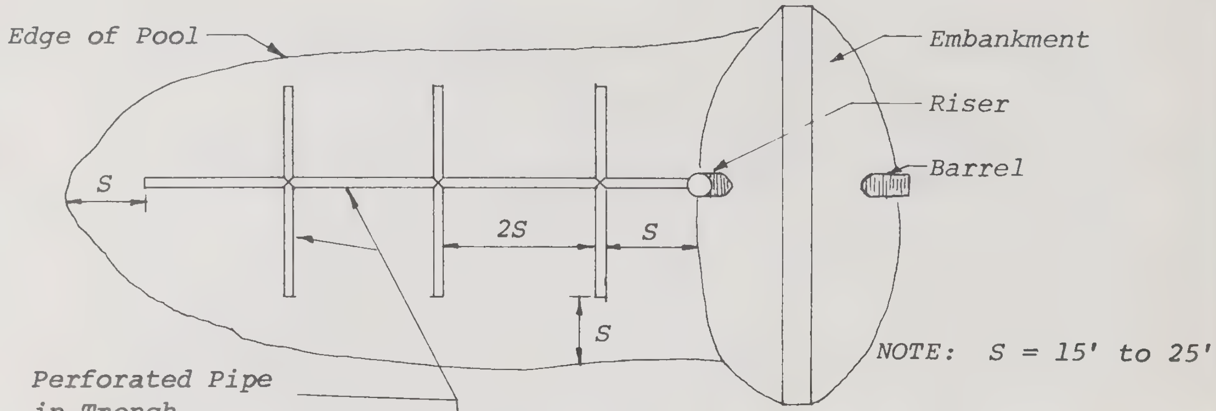
NOTE: Two other types of anti-seep collars are:

1. Corrugated metal, similar to upper detail, except shop welded to a short (4 ft.) section of the pipe and connected with connecting bands to the pipe.
2. Concrete, six inches thick formed around the pipe with #3 rebar spaced 15" horizontally and vertically.

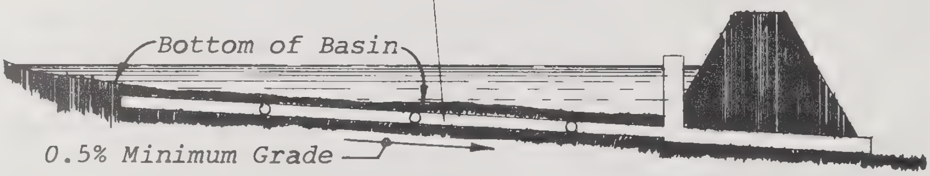
PARTIAL ELEVATION

Ref: Engr. Field Manual

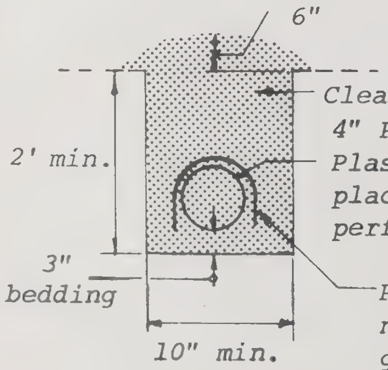
DEWATERING SEDIMENT BASIN WITH SUBSURFACE DRAIN



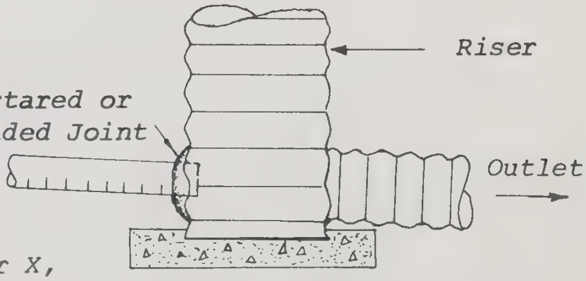
PLAN VIEW



PROFILE



CROSS SECTION
DRAIN PIPE IN TRENCH



RISER CONNECTION

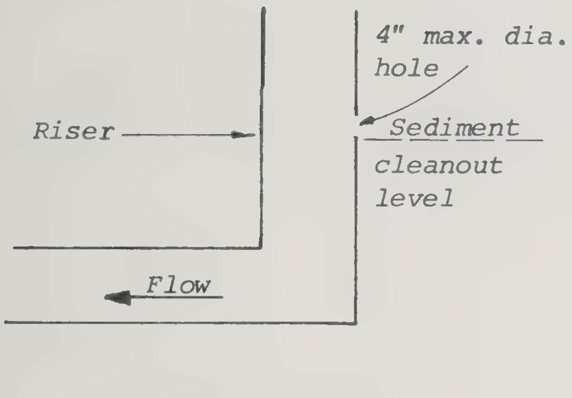
U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE College Park, Md.	DEWATERING SEDIMENT BASIN WITH SUBSURFACE DRAIN	

METHODS OF DEWATERING SEDIMENT BASIN DETENTION POOLS

The dewatering methods shown here are inexpensive and operate automatically. Other methods, such as pumping, may also be used.

METHOD	COMMENTS

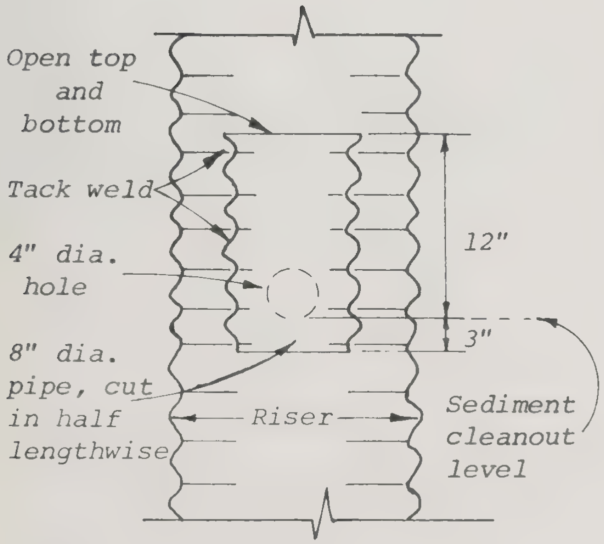
A.



CROSS-SECTION

Easy to construct
May clog with trash
Non-skimming
Capable of draining down to sediment clean-out level
Passes base flow without storage of water

B. Same as "A" except for skimming device, detailed below:

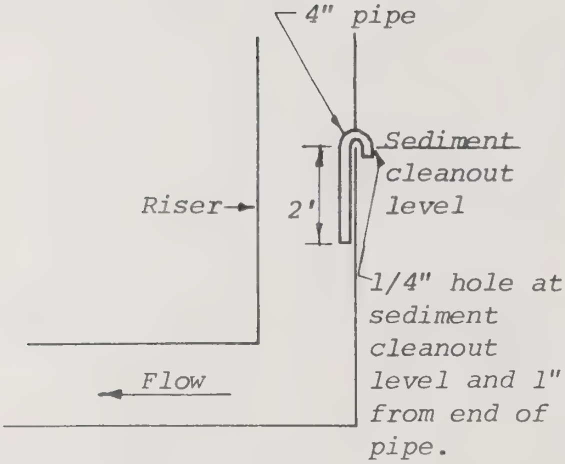


ELEVATION

Efficient skimmer
Non-clogging
Fairly easy to construct
Capable of draining down to sediment cleanout level
Passes base flow without storage of water

METHOD	COMMENTS

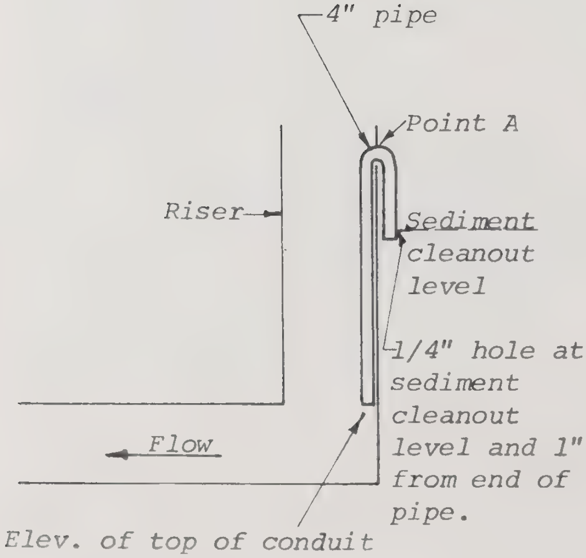
C.



CROSS-SECTION

Efficient skimmer
Capable of always draining down to sediment cleanout level
Passes base flow without storage of water
Higher discharge rate than "A" or "B".

D.



CROSS-SECTION

Efficient skimmer
Water must inundate point A to prime siphon. Therefore, small storms or low base flow rates will not prime siphon and drain pool.
Passes base flow (but with storage of water)
Higher discharge rate than "C"

PROCEDURE FOR DETERMINING OR ALTERING SEDIMENT BASIN SHAPE

As specified in the Standard & Specification, the pool area at the elevation of crest of the principal spillway shall have a length to width ratio of at least 2.0 to 1. The purpose of this requirement is to minimize the "short-circuiting" effect of the sediment laden inflow to the riser and thereby increase the effectiveness of the sediment basin. The purpose of this procedure is to prescribe the parameters, procedures and methods of determining and modifying the shape of the basin.

The length of the flow path (L) is the distance from the point of inflow to the riser (outflow point). The point of inflow is the point that the stream enters the normal pool (pool level at the riser crest elevation). The pool area (A) is the area of the normal pool. The effective width (W_e) is found by the equation:

$$W_e = \frac{A}{L}$$

and L:W ration $= \frac{L}{W_e}$

In the event there is more than one inflow point, any inflow point which conveys more than 30 percent of the total peak inflow rate shall meet the length-width ratio criteria.

The required basin shape may be obtained by proper site selection, by excavation or by constructing a baffle in the basin. The purpose of the baffle is to increase the effective flow length from the inflow point to the riser. Baffles shall be placed mid-way between the inflow point and the riser. The baffle length shall be as required to provide the minimum 2:1 length-width ratio. The effective length (L_e) shall be the shortest distance the water must flow from the inflow point around the end of the baffle to the outflow point. Then:

$$W_e = \frac{A}{L_e}$$

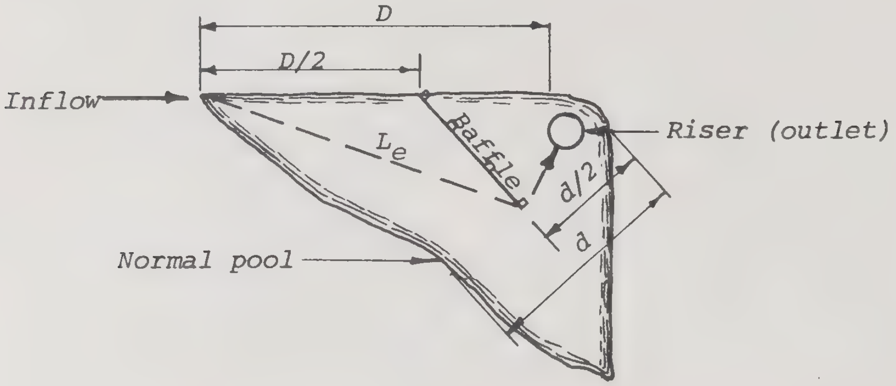
and L:W ratio $= \frac{L_e}{W_e}$

Three examples are shown on the following page. Note that for the special case in example C the water is allowed to go around both ends of the baffle and the effective length, $L_e = L_1 + L_2$. Otherwise, the length-width ratio computations are the same as shown above. This special case procedure for computing L_e is allowable only when the two flow paths are equal, i.e., when $L_1 = L_2$. A baffle detail is also shown.

SEDIMENT BASIN BAFFLES

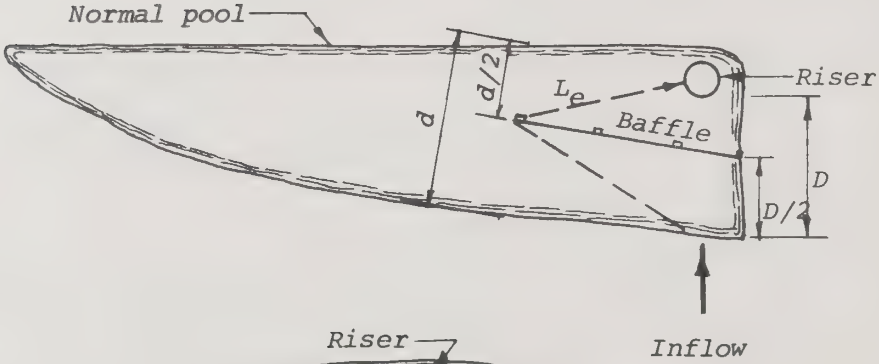
Examples: Plan Views - not to scale

A.

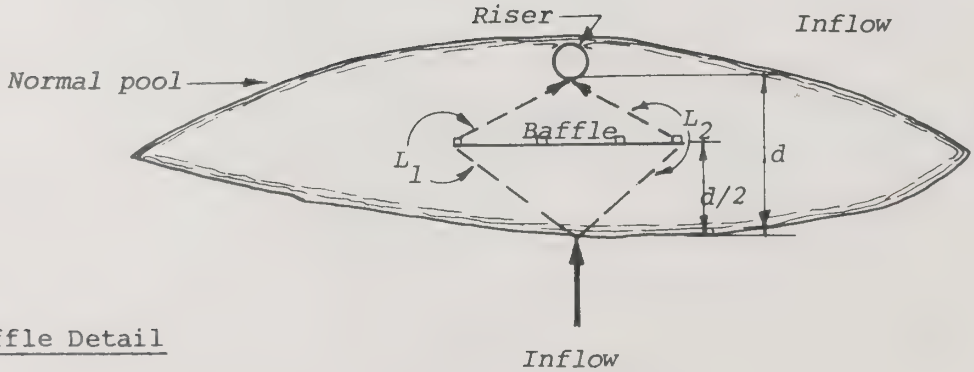


L_e = Total distance from the point of inflow around the baffle to the riser.

B.

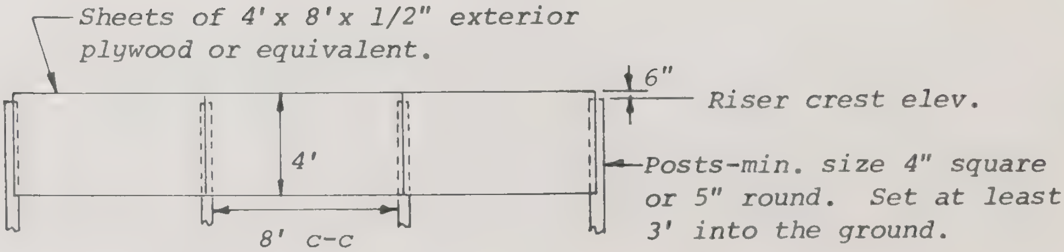


C.



$L_e = L_1 + L_2$

Baffle Detail



ELEVATION

APPENDIX C *

Sample Waterway and Diversion Design

The following material is provided to assist in the design of grassed waterways and diversions:

1. Graph of the Product of Velocity and Hydraulic Radius versus Mannings "n" for different degrees of vegetal retardance.

2. Table giving classification of vegetal cover based on degree of flow retardance by the vegetation.

3. Parabolic Waterway Design Tables for various grades and velocities for retardance "D", and top width and depth for retardance "C".

4. Trapezoidal Channel Design Tables for various grades, velocities and depths for retardance "C".

The use of these tables and graphs can best be shown by example problems, which are as follows:

<u>Problem 1</u>

Determine the non-erosive velocity and dimensions for stability and capacity for a waterway with parabolic cross-section.

Given:
- Runoff Q = 55 cfs
- Grade = 5.1 percent
- Vegetative cover Kentucky bluegrass
- Condition of vegetation
  - Good stand-mowed (3"-4") = "D" curve retardance
  - Good stand-headed (6"-12") = "C" curve retardance
- Permissible velocity = 4 ft./sec. (from Pg. 36.02)

Solution: Horizontally opposite 55 cfs on the Parabolic Waterway Design Table for Grade = 5.0 percent (slope table that is nearest 5.1%) and the columns headed V = 4.0 ft./sec., find T = 33 feet and D = 0.8 feet.

Therefore, a waterway with parabolic cross section, a top width of 33 feet, and a depth of 0.8 feet will carry 55 cfs at a maximum velocity of 4 feet per second when the vegetative lining is short (3" to 4" in height). This complies with the requirement for non-erosive velocity when vegetation is short ("D" retardance) and for capacity when vegetation is tall ("C" retardance).

Reference: USDA, Soil Conservation Service, National Engineering Handbook, Section 5, Hydraulics

*from USDA, Soil Conservation Service, College Park, Maryland. <u>Standards and Specifications for Soil Erosion and Sediment Control in Developing Areas.</u> July 1975.

Problem 2

Determine the non-erosive velocity and dimensions for a waterway with trapezoidal cross-section.

Given:	Runoff	Q = 55 cfs
	Grade	= 2 percent
	Side slopes	= 2:1
	Vegetative cover	Kentucky bluegrass
	Condition of vegetation	
	Good stand-headed (6"-12")	= "C" curve retardance
	Permissible velocity	= 5 ft./sec. (from Pg. 36.02)

Solution: Horizontally opposite 55 cfs on the Trapezoidal Channel Design Table for Grade = 2.0 percent, read across to the column for bottom width = 6 feet and read the D = 1.3 feet and V = 4.9 ft./sec.

Therefore, a waterway with trapezoidal cross-section, 2:1 side slope, bottom width of 6 feet, and a depth of 1.3 feet will carry 55 cfs at a maximum velocity of 4.9 feet per second for "C" curve retardance.

Problem 3

Determine the safe velocity and dimensions for a waterway with trapezoidal cross-section that does not fit the Trapezoidal Channel Design Tables.

Given:	Runoff	Q = 55 cfs
	Grade	= 3 percent
	Side slope	= 3:1
	Vegetative cover	Kentucky bluegrass

Condition of vegetation
Good stand-mowed (3"-4") = "D" curve retardance
Good stand-headed (6"-12") = "C" curve retardance
Permissible velocity = 5 ft./sec. (from Pg. 36.02)

Solution: The solution is a trial and error process. The first step is to design for stability when the vegetation is short ("D" retardance) and the second step is to design for capacity when the vegetation is tall ("C" retardance).

Step 1 - Stability

$Q = 55$ cfs.

$V_{max} = 5$ ft./sec.

$$A = \frac{Q}{V_{max}} = \frac{55}{5} = 11 \text{ sq.ft.}$$

Try Bottom Width = 12 feet

$A = bd + zd^2$

$11 = 12d + 3d^2$

Note: Solve for d by use of the quadratic equation.

$$ax^2 + bx + c = 0$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$3d^2 + 12d - 11 = 0$$

$$d = \frac{-12 \pm \sqrt{12^2 - 4(3)(-11)}}{2(3)}$$

$$d = \frac{-12 + 16.61}{6} = \frac{4.61}{6}$$

$$d = 0.77 \text{ feet}$$

Hydraulic Radius

$$r = \frac{\text{area}}{\text{wetted perimeter}} = \frac{bd + zd^2}{b + 2d\sqrt{z^2 + 1}}$$

$$r = \frac{12(0.77) + 3\ (0.77^2)}{12 + 2(0.77)\sqrt{3^2 + 1}}$$

$$r = \frac{9.24 + 1.78}{12 + 4.87}$$

$$r = \frac{11.02}{16.87} = 0.65$$

$$Vr = 5(0.65) = 3.25$$

From graph, page A-36.15 for Vr=3.25 and "D" retardance, read n = 0.04

$$V = \frac{1.486}{n}\ r^{2/3}\ s^{1/2}$$

$$= \frac{1.486}{0.04}\ (0.65^{2/3})(.03^{1/2}) = 4.83 \text{ ft./sec.}$$

Okay, but less than V_{max} - try slightly smaller channel.

Try bottom width = 10 feet

$A = bd + zd^2$

$11 = 10d + 3d^2$

$$d = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = 0.87$$

$$r = \frac{bd + zd^2}{b + 2d\sqrt{z^2 + 1}} = 0.71$$

$Vr = 3.55$

$n = 0.040$ from page A-36.15

$$V = \frac{1.486}{n} r^{2/3} s^{1/2} = 5.15$$ which is greater than V_{max}

Therefore, select design bottom width = 12 feet

Velocity = 4.83 feet/sec. for "D" retardance

$d = 0.8'$

Step 2 - Capacity check using "C" curve retardance. Determine additional depth needed to offset the increase retardance and decreased velocity.

Try d = 0.9 feet

$A = bd + zd^2 = (12)(0.9) + 3(.9^2) = 13.23$

$$r = \frac{A}{P} = \frac{13.23}{b+2d\sqrt{z^2+1}} = \frac{13.23}{12+2(.9)\sqrt{3^2+1}} = 0.75$$

Assume V = 4.4 ft./sec.

$Vr = (4.4)(0.75) = 3.30$

From graph, page A-36.15 for Vr = 3.30 and "C" retardance, read n = 0.046.

$$V = \frac{1.486}{0.046} (0.75^{2/3})(.03^{1/2}) = 4.62 \text{ ft./sec.}$$

which is greater than assumed value

Assume V = 4.6 ft./sec.

Vr = (4.6)(0.75) = 3.45

From graph, n = 0.046

$$V = \frac{1.486}{.046} (0.75^{2/3})(.03^{1/2}) = 4.62 \text{ ft./sec.}$$

which is close enough

Therefore, dimensions and velocities are as follows:

Bottom width = 12 feet

Side slopes = 3:1

For "D" retardance - V = 4.83 ft./sec.

d = 0.8 feet

For "C" retardance - V = 4.62 ft./sec.

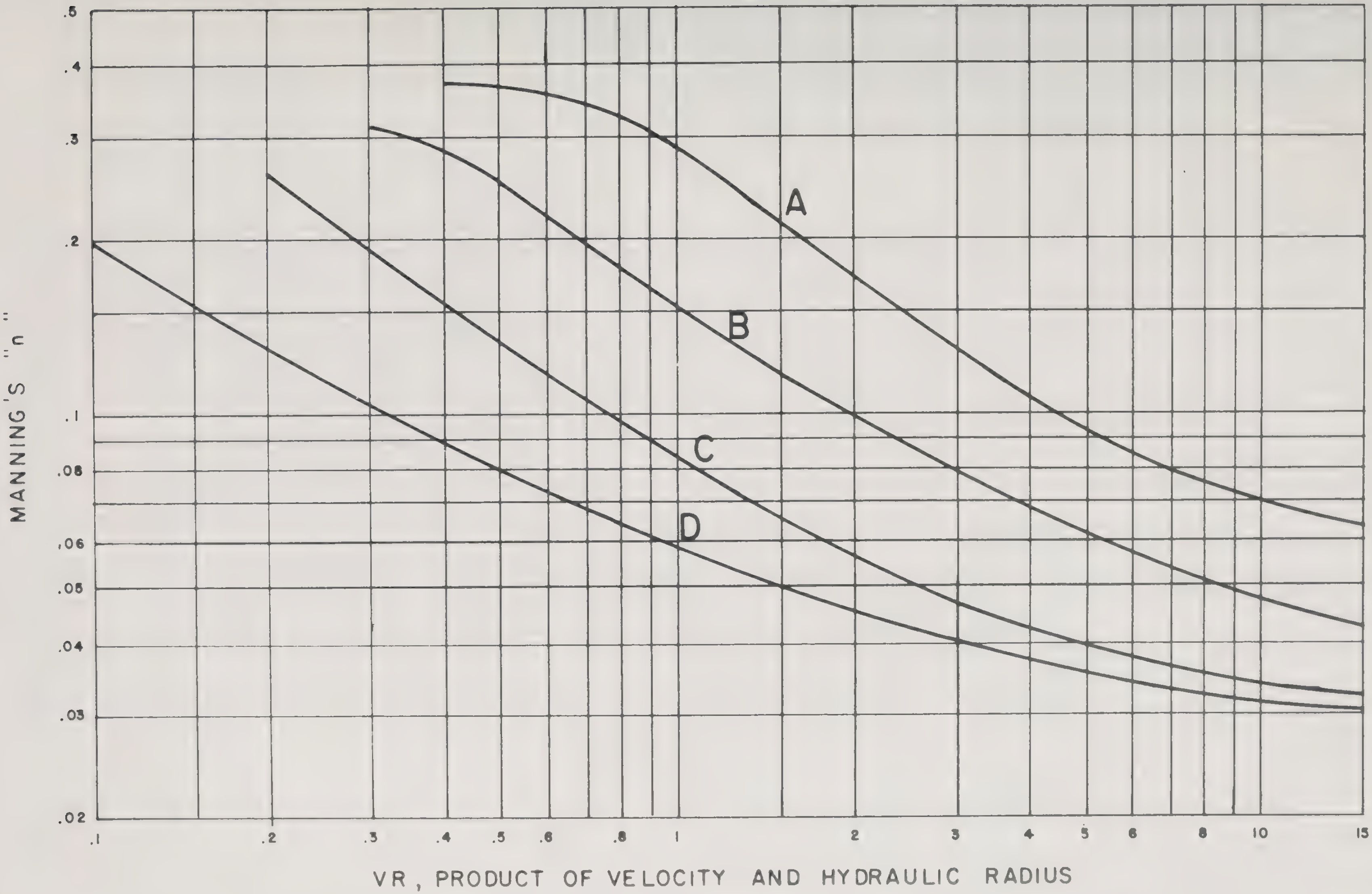
d = 0.9 feet + freeboard.

GRASSED WATERWAY AND DIVERSION

DESIGN TABLE (15)

Retardance	Cover	Stand	Condition and Height
A	Reed canarygrass	Excellent	Tall (Average 36")
	Kentucky 31 tall fescue	Excellent	Tall (Average 36")
B	Tufcote, Midland and Coastal bermudagrass	Good	Tall (Average 12")
	Reed canarygrass	Good	Mowed (Avg. 12 to 15")
	Kentucky 31 tall fescue	Good	Unmowed (Avg. 18")
	Red fescue	Good	Unmowed (Avg. 16")
	Kentucky bluegrass	Good	Unmowed (Avg. 16")
	Redtop	Good	Average 22"
C	Kentucky bluegrass	Good	Headed (6 to 12")
	Red fescue	Good	Headed (6 to 12")
	Tufcote, Midland and Coastal bermudagrass	Good	Mowed (Average 6")
	Redtop	Good	Headed (15 to 20")
D	Tufcote, Midland and Coastal bermudagrass	Good	Mowed (2 1/2")
	Red fescue	Good	Mowed (2 1/2")
	Kentucky bluegrass	Good	Mowed (2 - 5")

Classification of vegetal cover in waterways and diversions based on degree of flow retardance.



Manning's "n" related to velocity, hydraulic radius, and vegetal retardance. (15)

Parabolic Waterway Design

Grade 0.25 Percent(14)

Q cfs	V = 2.0		V = 2.5		V = 3.0		V = 3.5		V = 4.0		V = 4.5		V = 5.0		V = 5.5		V = 6.0	
	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D
15																		
20																		
25	10	2.4																
30	11	2.3																
35	13	2.3																
40	15	2.3	10	2.7														
45	17	2.2	12	2.6														
50	19	2.2	13	2.6														
55	20	2.2	14	2.6														
60	22	2.2	15	2.5														
65	24	2.2	17	2.5														
70	26	2.2	18	2.5	13	3.1												
75	28	2.2	19	2.5	13	3.0												
80	29	2.2	20	2.5	14	3.0												
90	33	2.2	23	2.5	16	3.0												
100	38	2.2	25	2.5	18	3.0												
110	40	2.2	28	2.5	19	2.9												
120	44	2.2	30	2.5	21	2.9	15	3.6										
130	48	2.2	33	2.5	23	2.9	16	3.6										
140	51	2.2	35	2.5	25	2.9	18	3.5										
150	55	2.2	37	2.5	26	2.9	19	3.5										
160	58	2.2	40	2.5	28	2.9	20	3.5										
170	62	2.2	42	2.5	30	2.9	21	3.5	17	4.0								
180	66	2.2	45	2.5	31	2.9	22	3.5	18	4.0								

Q = Flow in Cubic Feet per Second, V = Velocity in Feet per Second, T = Top Width in Feet
D = Depth in Feet

Parabolic Waterway Design

Grade 0.50 Percent

Q cfs	V = 2.0 T	V = 2.0 D	V = 2.5 T	V = 2.5 D	V = 3.0 T	V = 3.0 D	V = 3.5 T	V = 3.5 D	V = 4.0 T	V = 4.0 D	V = 4.5 T	V = 4.5 D	V = 5.0 T	V = 5.0 D	V = 5.5 T	V = 5.5 D	V = 6.0 T	V = 6.0 D
15	9	1.6																
20	11	1.6																
25	14	1.6	9	1.9														
30	17	1.6	11	1.9	8	2.2												
35	20	1.6	12	1.9	9	2.1												
40	22	1.6	14	1.8	11	2.1												
45	25	1.5	16	1.8	12	2.0												
50	28	1.5	18	1.8	13	2.0	10	2.4										
55	31	1.5	19	1.8	15	2.0	11	2.4										
60	33	1.5	21	1.8	16	2.0	11	2.4										
65	36	1.5	23	1.8	17	2.0	12	2.4										
70	39	1.5	24	1.8	18	2.0	13	2.3										
75	42	1.5	26	1.8	20	2.0	14	2.3	11	2.7								
80	44	1.5	28	1.8	21	2.0	15	2.3	12	2.7								
90	50	1.5	31	1.8	24	2.0	17	2.3	13	2.7								
100	55	1.5	35	1.8	26	2.0	19	2.3	15	2.6	12	3.0						
110	61	1.5	38	1.8	29	2.0	21	2.3	16	2.6	13	3.0						
120	66	1.5	42	1.8	31	2.0	22	2.3	18	2.6	14	2.9						
130	72	1.5	45	1.8	34	2.0	24	2.3	19	2.6	15	2.9						
140	77	1.5	48	1.8	36	2.0	26	2.3	20	2.6	16	2.9						
150	83	1.5	52	1.8	39	2.0	28	2.3	22	2.6	18	2.9	14	3.3				
160	88	1.5	55	1.8	41	2.0	30	2.3	23	2.6	19	2.9	15	3.3				
170	93	1.5	59	1.8	44	2.0	32	2.3	25	2.6	20	2.9	16	3.3				
180	99	1.5	62	1.8	47	2.0	33	2.3	26	2.6	21	2.9	17	3.3				

Q = Flow in Cubic Feet per Second, V = Velocity in Feet per Second, T = Top Width in Feet
D = Depth in Feet

V for Retardance "D",
T and D for Retardance "C"

Parabolic Waterway Design

Grade 0.75 Percent

Q cfs	V = 2.0		V = 2.5		V = 3.0		V = 3.5		V = 4.0		V = 4.5		V = 5.0		V = 5.5		V = 6.0	
	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D
15	12	1.3	7	1.6														
20	16	1.3	9	1.5														
25	19	1.3	11	1.5	8	1.7												
30	23	1.3	13	1.5	10	1.7	8	1.9										
35	27	1.3	15	1.5	11	1.7	9	1.9										
40	31	1.3	18	1.5	13	1.7	10	1.9										
45	35	1.3	20	1.5	14	1.7	11	1.8										
50	38	1.3	22	1.5	16	1.6	13	1.8	9	2.2								
55	42	1.3	24	1.5	18	1.6	14	1.8	10	2.1								
60	46	1.3	26	1.5	19	1.6	15	1.8	11	2.1								
65	50	1.3	28	1.5	21	1.6	16	1.8	12	2.1	10	2.4						
70	53	1.3	30	1.5	22	1.6	17	1.8	13	2.1	11	2.4						
75	57	1.3	33	1.5	24	1.6	19	1.8	14	2.1	11.	2.3						
80	61	1.3	35	1.5	25	1.6	20	1.8	15	2.1	12	2.3						
90	68	1.3	39	1.5	28	1.6	22	1.8	16	2.1	13	2.3	11	2.6				
100	76	1.3	43	1.5	32	1.6	25	1.8	18	2.1	15	2.3	12	2.6				
110	83	1.3	48	1.5	35	1.6	27	1.8	20	2.0	16	2.3	13	2.6				
120	91	1.3	52	1.5	38	1.6	30	1.8	22	2.1	18	2.3	15	2.5	12	2.9		
130	98	1.3	56	1.5	41	1.6	32	1.8	23	2.1	19	2.2	16	2.5	13	2.8		
140	106	1.3	60	1.5	44	1.6	34	1.8	25	2.0	21	2.3	17	2.5	14	2.8		
150	113	1.3	65	1.5	47	1.6	37	1.8	27	2.0	22	2.2	18	2.5	15	2.8		
160	121	1.3	69	1.5	50	1.6	39	1.8	29	2.0	24	2.2	19	2.5	16	2.8	13	3.1
170	128	1.3	73	1.5	53	1.6	42	1.8	30	2.0	25	2.2	20	2.5	17	2.8	14	3.1
180	135	1.3	77	1.5	56	1.6	44	1.8	32	2.0	27	2.2	22	2.5	18	2.8	15	3.1

Q = Flow in Cubic Feet per Second, V = Velocity in Feet per Second, T = Top Width in Feet
D = Depth in Feet

V for Retardance "D",
T and D for Retardance "C"

Parabolic Waterway Design

Grade 1.0 Percent

Q cfs	V = 2.0 T	V = 2.0 D	V = 2.5 T	V = 2.5 D	V = 3.0 T	V = 3.0 D	V = 3.5 T	V = 3.5 D	V = 4.0 T	V = 4.0 D	V = 4.5 T	V = 4.5 D	V = 5.0 T	V = 5.0 D	V = 5.5 T	V = 5.5 D	V = 6.0 T	V = 6.0 D
15	13	1.1	8	1.3														
20	18	1.1	11	1.3	8	1.5												
25	22	1.1	14	1.3	9	1.5	8	1.6										
30	27	1.1	17	1.3	11	1.5	9	1.6										
35	31	1.1	19	1.3	13	1.5	11	1.6	8	1.8								
40	35	1.1	22	1.3	15	1.4	12	1.6	9	1.8								
45	40	1.1	25	1.3	17	1.5	13	1.6	10	1.8								
50	44	1.1	28	1.3	19	1.4	15	1.6	11	1.8	9	2.0						
55	48	1.1	30	1.3	20	1.4	16	1.5	12	1.8	10	2.0						
60	53	1.1	33	1.3	22	1.4	18	1.5	14	1.7	10	2.0						
65	57	1.1	36	1.3	24	1.4	19	1.5	15	1.7	11	2.0	9	2.2				
70	61	1.1	38	1.3	26	1.4	21	1.5	16	1.7	12	2.0	10	2.2				
75	66	1.1	41	1.3	28	1.4	22	1.5	17	1.7	13	2.0	11	2.2				
80	70	1.1	44	1.3	29	1.4	24	1.5	18	1.7	14	2.0	11	2.2				
90	79	1.1	49	1.3	33	1.4	27	1.5	20	1.7	15	1.9	13	2.2	11	2.4		
100	87	1.1	55	1.3	37	1.4	29	1.5	22	1.7	17	1.9	14	2.2	12	2.4		
110	96	1.1	60	1.3	40	1.4	32	1.5	24	1.7	19	1.9	15	2.1	13	2.4	11	2.6
120	104	1.1	65	1.3	44	1.4	35	1.5	27	1.7	20	1.9	17	2.1	14	2.4	12	2.6
130	113	1.1	71	1.3	47	1.4	38	1.5	29	1.7	22	1.9	18	2.1	15	2.4	13	2.6
140	121	1.1	76	1.3	51	1.4	41	1.5	31	1.7	24	1.9	20	2.1	16	2.3	14	2.6
150	130	1.1	81	1.3	55	1.4	44	1.5	33	1.7	25	1.9	21	2.1	17	2.4	15	2.6
160	138	1.1	87	1.3	58	1.4	47	1.5	35	1.7	27	1.9	22	2.1	19	2.3	16	2.5
170	147	1.1	92	1.3	62	1.4	50	1.5	38	1.7	29	1.9	24	2.1	20	2.3	17	2.5
180	155	1.1	97	1.3	65	1.4	53	1.5	40	1.7	30	1.9	25	2.1	21	2.3	18	2.5

Q = Flow in Cubic Feet per Second, V = Velocity in Feet per Second, T = Top Width in Feet
D = Depth in Feet

Parabolic Waterway Design

Grade 1.25 Percent

Q cfs	V = 2.0 T	V = 2.0 D	V = 2.5 T	V = 2.5 D	V = 3.0 T	V = 3.0 D	V = 3.5 T	V = 3.5 D	V = 4.0 T	V = 4.0 D	V = 4.5 T	V = 4.5 D	V = 5.0 T	V = 5.0 D	V = 5.5 T	V = 5.5 D	V = 6.0 T	V = 6.0 D
15	15	1.0	10	1.2	7	1.4												
20	20	1.0	13	1.1	9	1.3	7	1.5										
25	25	1.0	16	1.1	11	1.3	8	1.5	7	1.6								
30	31	1.0	19	1.1	13	1.3	10	1.4	8	1.6								
35	36	1.0	23	1.1	15	1.3	11	1.4	9	1.6	7	1.8						
40	41	1.0	26	1.1	17	1.3	13	1.4	11	1.6	8	1.8						
45	46	1.0	29	1.1	19	1.3	14	1.4	12	1.5	9	1.7						
50	50	1.0	32	1.1	21	1.3	16	1.4	13	1.5	10	1.7	8	2.0				
55	55	1.0	35	1.1	23	1.3	18	1.4	14	1.5	11	1.7	9	1.9				
60	60	1.0	38	1.1	26	1.3	19	1.4	16	1.5	12	1.7	10	1.9				
65	65	1.0	41	1.1	28	1.3	21	1.4	17	1.5	13	1.7	11	1.9	9	2.2		
70	70	1.0	45	1.1	30	1.3	22	1.4	18	1.5	14	1.7	11	1.9	9	2.2		
75	75	1.0	48	1.1	32	1.3	24	1.4	19	1.5	15	1.7	12	1.9	10	2.1		
80	80	1.0	51	1.1	34	1.3	25	1.4	21	1.5	16	1.7	13	1.9	11	2.1	9	2.3
90	90	1.0	57	1.1	38	1.3	29	1.4	23	1.5	18	1.7	15	1.9	12	2.1	10	2.3
100	100	1.0	63	1.1	42	1.3	32	1.4	26	1.5	20	1.7	16	1.9	13	2.1	11	2.3
110	109	1.0	70	1.1	46	1.3	35	1.4	28	1.5	22	1.7	18	1.9	14	2.1	12	2.2
120	119	1.0	76	1.1	51	1.3	38	1.4	31	1.5	24	1.7	19	1.8	16	2.1	14	2.2
130	129	1.0	82	1.1	55	1.3	41	1.4	33	1.5	26	1.7	21	1.8	17	2.1	15	2.2
140	139	1.0	88	1.1	59	1.3	44	1.4	36	1.5	28	1.7	23	1.8	18	2.1	16	2.2
150	148	1.0	94	1.1	63	1.3	47	1.4	38	1.5	30	1.7	24	1.8	19	2.0	17	2.2
160	158	1.0	101	1.1	67	1.3	50	1.4	41	1.5	32	1.7	26	1.8	21	2.1	18	2.2
170	168	1.0	107	1.1	71	1.3	54	1.4	43	1.5	34	1.7	27	1.8	22	2.1	19	2.2
180	177	1.0	113	1.1	75	1.3	57	1.4	46	1.5	36	1.7	29	1.8	23	2.1	20	2.2

Q = Flow in Cubic Feet per Second, V = Velocity in Feet per Second, T = Top Width in Feet
D = Depth in Feet

V for Retardance "D",
T and D for Retardance "C"

Parabolic Waterway Design

Grade 1.50 Percent

Q cfs	V = 2.0		V = 2.5		V = 3.0		V = 3.5		V = 4.0		V = 4.5		V = 5.0		V = 5.5		V = 6.0	
	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D
15	17	0.9	11	1.1	8	1.2												
20	23	0.9	15	1.0	10	1.2	7	1.4	6	1.5								
25	28	0.9	19	1.0	12	1.2	9	1.4	7	1.5								
30	34	0.9	22	1.0	15	1.2	10	1.3	8	1.5	7	1.6						
35	40	0.9	26	1.0	17	1.1	12	1.3	10	1.4	8	1.6						
40	45	0.9	30	1.0	20	1.2	14	1.3	11	1.4	9	1.6	7	1.8				
45	51	0.9	33	1.0	22	1.1	15	1.3	12	1.4	10	1.5	8	1.8				
50	56	0.9	37	1.0	25	1.1	17	1.3	14	1.4	11	1.5	9	1.8				
55	62	0.9	41	1.0	27	1.1	19	1.3	15	1.4	12	1.5	10	1.7	8	1.9		
60	67	0.9	44	1.0	30	1.1	20	1.3	16	1.4	14	1.5	11	1.7	9	1.9		
65	73	0.9	48	1.0	32	1.1	22	1.3	18	1.4	15	1.5	11	1.7	10	1.9		
70	78	0.9	51	1.0	34	1.1	24	1.3	19	1.4	16	1.5	12	1.7	10	1.9	9	2.1
75	83	0.9	55	1.0	37	1.1	25	1.3	21	1.4	17	1.5	13	1.7	11	1.9	9	2.1
80	89	0.9	59	1.0	39	1.1	27	1.3	22	1.4	18	1.5	14	1.7	12	1.9	10	2.1
90	100	0.9	66	1.0	44	1.1	30	1.3	25	1.4	20	1.5	16	1.7	13	1.9	11	2.0
100	111	0.9	73	1.0	49	1.1	33	1.3	27	1.4	22	1.5	17	1.7	15	1.9	12	2.0
110	121	0.9	80	1.0	54	1.1	37	1.3	30	1.4	25	1.5	19	1.7	16	1.8	14	2.0
120	132	0.9	87	1.0	58	1.1	40	1.3	33	1.4	27	1.5	21	1.7	18	1.9	15	2.0
130	143	0.9	95	1.0	63	1.1	43	1.3	35	1.4	29	1.5	22	1.7	19	1.8	16	2.0
140	154	0.9	102	1.0	68	1.1	47	1.3	38	1.4	31	1.5	24	1.7	20	1.8	17	2.0
150	164	0.9	109	1.0	73	1.1	50	1.3	41	1.4	33	1.5	26	1.7	22	1.8	18	2.0
160	175	0.9	116	1.0	78	1.1	53	1.3	43	1.4	36	1.5	27	1.7	23	1.8	20	2.0
170	186	0.9	123	1.0	82	1.1	57	1.3	46	1.4	38	1.5	29	1.7	25	1.8	21	2.0
180	196	0.9	130	1.0	87	1.1	60	1.3	49	1.4	40	1.5	31	1.7	26	1.8	22	2.0

Q = Flow in Cubic Feet per Second, V = Velocity in Feet per Second, T = Top Width in Feet
D = Depth in Feet

Parabolic Waterway Design

Grade 1.75 Percent

Q cfs	V = 2.0		V = 2.5		V = 3.0		V = 4.5		V = 4.0		V = 4.5		V = 5.0		V = 5.5		V = 6.0	
	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D
15	19	0.9	12	1.0	9	1.1	6	1.3										
20	25	0.9	16	1.0	11	1.1	8	1.3	7	1.3								
25	31	0.9	20	1.0	14	1.1	10	1.2	8	1.3	7	1.5						
30	37	0.9	24	1.0	17	1.1	12	1.2	10	1.3	8	1.4						
35	43	0.9	28	1.0	20	1.1	13	1.2	11	1.3	9	1.4	7	1.6				
40	49	0.9	32	1.0	22	1.1	15	1.2	13	1.3	10	1.4	8	1.6				
45	55	0.9	36	1.0	25	1.1	17	1.2	14	1.3	12	1.4	9	1.6	8	1.7		
50	61	0.9	40	1.0	28	1.1	19	1.2	16	1.3	13	1.4	10	1.5	8	1.7		
55	67	0.9	44	1.0	31	1.1	21	1.2	17	1.3	14	1.4	11	1.5	9	1.7	8	1.9
60	73	0.9	48	1.0	33	1.1	23	1.2	19	1.3	15	1.4	12	1.5	10	1.7	8	1.9
65	78	0.9	52	1.0	36	1.1	25	1.2	21	1.3	17	1.4	13	1.5	11	1.7	9	1.9
70	84	0.9	56	1.0	39	1.1	27	1.2	22	1.3	18	1.4	14	1.5	12	1.7	10	1.9
75	90	0.9	59	1.0	42	1.1	29	1.2	24	1.3	19	1.4	15	1.5	12	1.7	10	1.9
80	96	0.9	63	1.0	44	1.1	30	1.2	25	1.3	20	1.4	16	1.5	13	1.7	11	1.9
90	108	0.9	71	1.0	50	1.1	34	1.2	28	1.3	23	1.4	18	1.5	15	1.7	12	1.9
100	120	0.9	79	1.0	55	1.1	38	1.2	31	1.3	25	1.4	20	1.5	16	1.7	13	1.9
110	131	0.9	87	1.0	61	1.1	42	1.2	34	1.3	28	1.4	22	1.5	18	1.7	15	1.8
120	143	0.9	94	1.0	66	1.1	45	1.2	38	1.3	30	1.4	24	1.5	20	1.7	16	1.8
130	155	0.9	102	1.0	71	1.1	49	1.2	41	1.3	33	1.4	26	1.5	21	1.7	17	1.8
140	166	0.9	110	1.0	77	1.1	53	1.2	44	1.3	35	1.4	28	1.5	23	1.6	19	1.8
150	178	0.9	117	1.0	82	1.1	56	1.2	47	1.3	38	1.4	30	1.5	24	1.6	20	1.8
160	189	0.9	125	1.0	88	1.1	60	1.2	50	1.3	40	1.4	31	1.5	26	1.6	21	1.8
170	201	0.9	132	1.0	93	1.1	64	1.2	53	1.3	43	1.4	33	1.5	28	1.6	23	1.8
180	212	0.9	140	1.0	98	1.1	67	1.2	56	1.3	45	1.4	35	1.5	29	1.6	24	1.8

Q = Flow in Cubic Feet per Second, V = Velocity in Feet per Second, T = Top Width in Feet
D = Depth in Feet

Parabolic Waterway Design

Grade 2.0 Percent

Q cfs	V = 2.0		V = 2.5		V = 3.0		V = 3.5		V = 4.0		V = 4.5		V = 5.0		V = 5.5		V = 6.0	
	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D
15	21	0.8	13	0.9	9	1.0	7	1.2										
20	28	0.8	17	0.9	12	1.0	9	1.1	7	1.3	5	1.4						
25	35	0.8	21	0.9	15	1.0	11	1.1	8	1.3	7	1.4						
30	41	0.8	26	0.9	18	1.0	13	1.1	10	1.2	8	1.3	7	1.5				
35	48	0.8	30	0.9	22	1.0	15	1.1	11	1.2	9	1.3	8	1.5				
40	55	0.8	34	0.9	25	1.0	18	1.1	13	1.2	11	1.3	9	1.5	7	1.7		
45	62	0.8	38	0.9	28	1.0	20	1.1	14	1.2	12	1.3	10	1.4	8	1.6		
50	68	0.8	42	0.9	31	1.0	22	1.1	16	1.2	13	1.3	11	1.4	9	1.6	8	1.7
55	75	0.8	46	0.9	34	1.0	24	1.1	17	1.2	14	1.3	12	1.4	10	1.6	8	1.7
60	82	0.8	51	0.9	37	1.0	26	1.1	19	1.2	16	1.3	13	1.4	11	1.6	9	1.7
65	88	0.8	55	0.9	40	1.0	28	1.1	21	1.2	17	1.3	14	1.4	11	1.6	10	1.7
70	95	0.8	59	0.9	43	1.0	30	1.1	22	1.2	18	1.3	15	1.4	12	1.6	10	1.7
75	101	0.8	63	0.9	46	1.0	32	1.1	24	1.2	20	1.3	16	1.4	13	1.6	11	1.7
80	108	0.8	67	0.9	48	1.0	35	1.1	25	1.2	21	1.3	17	1.4	14	1.6	12	1.7
90	121	0.8	75	0.9	54	1.0	39	1.1	28	1.2	23	1.3	19	1.4	16	1.6	13	1.7
100	134	0.8	83	0.9	60	1.0	43	1.1	31	1.2	26	1.3	21	1.4	17	1.6	15	1.7
110	147	0.8	92	0.9	66	1.0	47	1.1	34	1.2	28	1.3	23	1.4	19	1.5	16	1.7
120	160	0.8	100	0.9	72	1.0	52	1.1	38	1.2	31	1.3	26	1.4	21	1.5	18	1.7
130	173	0.8	108	0.9	78	1.0	56	1.1	41	1.2	34	1.3	28	1.4	23	1.5	19	1.7
140	186	0.8	116	0.9	84	1.0	60	1.1	44	1.2	36	1.3	30	1.4	24	1.5	21	1.7
150	199	0.8	124	0.9	90	1.0	64	1.1	47	1.2	39	1.3	32	1.4	26	1.5	22	1.7
160	212	0.8	132	0.9	96	1.0	69	1.1	50	1.2	41	1.3	34	1.4	28	1.5	23	1.7
170	225	0.8	140	0.9	102	1.0	73	1.1	53	1.2	44	1.3	36	1.4	29	1.5	25	1.7
180	238	0.8	148	0.9	108	1.0	77	1.1	56	1.2	46	1.3	38	1.4	31	1.5	26	1.7

Q = Flow in Cubic Feet per Second, V = Velocity in Feet per Second, T = Top Width in Feet
D = Depth in Feet

Parabolic Waterway Design

Grade 3.0 Percent

Q cfs	V = 2.0		V = 2.5		V = 3.0		V = 3.5		V = 4.0		V = 4.5		V = 5.0		V = 5.5		V = 6.0	
	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D
15	24	0.7	16	0.8	11	0.8	9	0.9	7	1.0	5	1.2						
20	31	0.7	22	0.8	15	0.8	12	0.9	9	1.0	7	1.1	6	1.2				
25	39	0.7	27	0.8	19	0.8	15	0.9	11	1.0	8	1.1	7	1.2	6	1.3		
30	47	0.7	32	0.8	23	0.8	17	0.9	13	1.0	10	1.1	9	1.2	7	1.2	6	1.4
35	55	0.7	38	0.8	26	0.8	20	0.9	15	1.0	11	1.1	10	1.1	8	1.2	7	1.4
40	62	0.7	43	0.8	30	0.8	23	0.9	17	1.0	13	1.1	12	1.1	9	1.2	8	1.4
45	70	0.7	48	0.8	34	0.8	26	0.9	19	1.0	15	1.1	13	1.1	11	1.2	9	1.3
50	77	0.7	54	0.8	38	0.8	29	0.9	21	1.0	16	1.1	14	1.1	12	1.2	9	1.3
55	85	0.7	59	0.8	41	0.8	32	0.9	23	1.0	18	1.1	16	1.1	13	1.2	10	1.4
60	93	0.7	64	0.8	45	0.8	35	0.9	26	1.0	19	1.1	17	1.1	14	1.2	11	1.3
65	100	0.7	70	0.8	49	0.8	37	0.9	28	1.0	21	1.1	19	1.1	15	1.2	12	1.3
70	107	0.7	74	0.8	52	0.8	40	0.9	30	1.0	22	1.1	20	1.1	16	1.2	13	1.3
75	115	0.7	79	0.8	56	0.8	43	0.9	32	1.0	24	1.1	21	1.1	18	1.2	14	1.3
80	122	0.7	85	0.8	59	0.8	46	0.9	34	1.0	26	1.1	23	1.1	19	1.2	15	1.3
90	137	0.7	95	0.8	67	0.8	51	0.9	38	1.0	29	1.1	26	1.1	21	1.2	17	1.3
100	152	0.7	105	0.8	74	0.8	57	0.9	42	1.0	32	1.1	28	1.1	23	1.2	19	1.3
110	167	0.7	116	0.8	81	0.8	63	0.9	46	1.0	35	1.1	31	1.1	26	1.2	21	1.3
120	181	0.7	126	0.8	89	0.8	68	0.9	51	1.0	38	1.1	34	1.1	28	1.2	22	1.3
130	196	0.7	136	0.8	96	0.8	74	0.9	55	1.0	41	1.1	37	1.1	30	1.2	24	1.3
140	211	0.7	146	0.8	103	0.8	79	0.9	59	1.0	44	1.1	39	1.1	32	1.2	26	1.3
150	225	0.7	156	0.8	110	0.8	85	0.9	63	1.0	47	1.1	42	1.1	35	1.2	28	1.3
160	239	0.7	166	0.8	117	0.8	90	0.9	67	1.0	50	1.1	45	1.1	37	1.2	30	1.3
170	254	0.7	176	0.8	124	0.8	96	0.9	71	1.0	54	1.1	48	1.1	39	1.2	32	1.3
180	268	0.7	186	0.8	131	0.8	101	0.9	75	1.0	57	1.1	50	1.1	41	1.2	33	1.3

Q = Flow in Cubic Feet per Second, V = Velocity in Feet per Second, T = Top Width in Feet
D = Depth in Feet

V for Retardance "D",
T and D for Retardance "C"

Parabolic Waterway Design

Grade 4.0 Percent

Q cfs	V = 2.0 T	V = 2.0 D	V = 2.5 T	V = 2.5 D	V = 3.0 T	V = 3.0 D	V = 3.5 T	V = 3.5 D	V = 4.0 T	V = 4.0 D	V = 4.5 T	V = 4.5 D	V = 5.0 T	V = 5.0 D	V = 5.5 T	V = 5.5 D	V = 6.0 T	V = 6.0 D
15	28	0.6	20	0.7	14	0.7	10	0.8	8	0.9	6	0.9	5	1.1				
20	37	0.6	27	0.7	19	0.7	14	0.8	11	0.8	8	0.9	6	1.0	6	1.1		
25	46	0.6	33	0.7	23	0.7	17	0.8	13	0.8	11	0.9	8	1.0	7	1.1	6	1.2
30	55	0.6	40	0.7	28	0.7	20	0.8	16	0.8	13	0.9	10	1.0	8	1.1	7	1.2
35	64	0.6	46	0.7	32	0.7	24	0.8	18	0.8	15	0.9	11	1.0	10	1.1	8	1.2
40	73	0.6	52	0.7	37	0.7	27	0.8	21	0.8	17	0.9	13	1.0	11	1.0	9	1.1
45	82	0.6	59	0.7	41	0.7	30	0.8	23	0.8	19	0.9	14	1.0	12	1.1	10	1.1
50	91	0.6	65	0.7	46	0.7	34	0.8	26	0.8	21	0.9	16	1.0	14	1.1	11	1.1
55	100	0.6	72	0.7	50	0.7	37	0.8	29	0.8	23	0.9	17	1.0	15	1.0	12	1.1
60	109	0.6	78	0.7	55	0.7	40	0.8	31	0.8	25	0.9	19	1.0	16	1.0	13	1.1
65	117	0.6	84	0.7	59	0.7	44	0.8	34	0.8	27	0.9	20	1.0	18	1.1	14	1.1
70	126	0.6	90	0.7	63	0.7	47	0.8	36	0.8	29	0.9	22	1.0	19	1.0	15	1.1
75	135	0.6	97	0.7	68	0.7	50	0.8	39	0.8	31	0.8	24	1.0	20	1.0	17	1.1
80	143	0.6	103	0.7	72	0.7	53	0.8	41	0.8	33	0.9	25	1.0	21	1.0	18	1.1
90	161	0.6	115	0.7	81	0.7	60	0.8	46	0.8	37	0.9	28	1.0	24	1.0	20	1.1
100	178	0.6	128	0.7	90	0.7	66	0.8	51	0.8	41	0.9	31	1.0	27	1.0	22	1.1
110	195	0.6	140	0.7	99	0.7	73	0.8	56	0.8	45	0.9	34	1.0	29	1.0	24	1.1
120	213	0.6	153	0.7	107	0.7	79	0.8	61	0.8	49	0.9	37	1.0	32	1.0	26	1.1
130	230	0.6	165	0.7	116	0.7	86	0.8	66	0.8	53	0.9	40	1.0	35	1.0	28	1.1
140	247	0.6	177	0.7	125	0.7	92	0.8	71	0.8	57	0.9	43	1.0	37	1.0	31	1.1
150	264	0.6	189	0.7	133	0.7	99	0.8	76	0.8	61	0.9	47	1.0	40	1.0	33	1.1
160	280	0.6	201	0.7	142	0.7	105	0.8	81	0.8	65	0.9	50	1.0	42	1.0	35	1.1
170	297	0.6	213	0.7	150	0.7	112	0.8	86	0.8	69	0.9	53	1.0	45	1.0	37	1.1
180	314	0.6	225	0.7	159	0.7	118	0.8	91	0.8	73	0.9	56	1.0	48	1.0	39	1.1

Q = Flow in Cubic Feet per Second, V = Velocity in Feet per Second, T = Top Width in Feet
D = Depth in Feet

V for Retardance "D",
T and D for Retardance "C"

Parabolic Waterway Design

Grade 5.0 Percent

Q cfs	V = 2.0 T	V = 2.0 D	V = 2.5 T	V = 2.5 D	V = 3.0 T	V = 3.0 D	V = 3.5 T	V = 3.5 D	V = 4.0 T	V = 4.0 D	V = 4.5 T	V = 4.5 D	V = 5.0 T	V = 5.0 D	V = 5.5 T	V = 5.5 D	V = 6.0 T	V = 6.0 D
15	29	0.6	21	0.6	15	0.7	12	0.7	9	0.8	7	0.8	6	0.9	5	1.0		
20	39	0.6	28	0.6	20	0.7	16	0.7	12	0.8	10	0.8	8	0.9	6	1.0	5	1.1
25	49	0.6	35	0.6	25	0.7	20	0.7	15	0.8	12	0.8	10	0.9	8	1.0	7	1.0
30	58	0.6	42	0.6	30	0.7	24	0.7	18	0.8	14	0.8	11	0.9	9	1.0	8	1.0
35	68	0.6	49	0.6	35	0.7	28	0.7	21	0.8	17	0.8	13	0.9	11	0.9	9	1.0
40	77	0.6	56	0.6	40	0.7	32	0.7	24	0.8	19	0.8	15	0.9	12	0.9	10	1.0
45	86	0.6	63	0.6	44	0.7	36	0.7	27	0.8	21	0.8	17	0.9	14	0.9	12	1.0
50	96	0.6	69	0.6	49	0.7	40	0.7	30	0.8	24	0.8	19	0.9	15	0.9	13	1.0
55	105	0.6	76	0.6	54	0.7	44	0.7	33	0.8	26	0.8	21	0.9	17	0.9	14	1.0
60	114	0.6	83	0.6	59	0.7	48	0.7	36	0.8	28	0.8	22	0.9	18	0.9	15	1.0
65	123	0.6	89	0.6	63	0.7	52	0.7	38	0.8	31	0.8	24	0.9	19	0.9	17	1.0
70	132	0.6	96	0.6	68	0.7	56	0.7	41	0.8	33	0.8	26	0.9	21	0.9	18	1.0
75	142	0.6	102	0.6	73	0.7	59	0.7	44	0.8	35	0.8	28	0.9	22	0.9	19	1.0
80	151	0.6	109	0.6	78	0.7	63	0.7	47	0.8	37	0.8	30	0.9	24	0.9	20	1.0
90	169	0.6	122	0.6	87	0.7	71	0.7	53	0.8	42	0.8	33	0.9	27	0.9	23	1.0
100	187	0.6	136	0.6	97	0.7	79	0.7	59	0.8	47	0.8	37	0.9	30	0.9	26	1.0
110	205	0.6	149	0.6	106	0.7	86	0.7	64	0.8	51	0.8	41	0.9	33	0.9	28	1.0
120	223	0.6	162	0.6	115	0.7	94	0.7	70	0.8	56	0.8	44	0.9	35	0.9	31	1.0
130	241	0.6	175	0.6	125	0.7	102	0.7	76	0.8	60	0.8	48	0.9	38	0.9	33	1.0
140	259	0.6	188	0.6	134	0.7	109	0.7	81	0.8	65	0.8	52	0.9	41	0.9	36	1.0
150	276	0.6	201	0.6	143	0.7	117	0.7	87	0.8	69	0.8	55	0.9	44	0.9	38	1.0
160	294	0.6	213	0.6	152	0.7	124	0.7	93	0.8	74	0.8	59	0.9	47	0.9	40	1.0
170	311	0.6	226	0.6	162	0.7	132	0.7	98	0.8	78	0.8	62	0.9	50	0.9	43	1.0
180	329	0.6	239	0.6	171	0.7	139	0.7	104	0.8	83	0.8	66	0.9	53	0.9	45	1.0

Q = Flow in Cubic Feet per Second, V = Velocity in Feet per Second, T = Top Width in Feet
D = Depth in Feet

V for Retardance "D",
T and D for Retardance "C"

Parabolic Waterway Design

Grade 6.0 Percent

Q cfs	V = 2.0 T	V = 2.0 D	V = 2.5 T	V = 2.5 D	V = 3.0 T	V = 3.0 D	V = 3.5 T	V = 3.5 D	V = 4.0 T	V = 4.0 D	V = 4.5 T	V = 4.5 D	V = 5.0 T	V = 5.0 D	V = 5.5 T	V = 5.5 D	V = 6.0 T	V = 6.0 D
15	35	0.5	23	0.6	17	0.6	13	0.7	10	0.7	8	0.8	7	0.8	5	0.9	4	1.0
20	46	0.5	30	0.6	22	0.6	17	0.7	13	0.7	11	0.7	9	0.8	7	0.9	6	1.0
25	57	0.5	37	0.6	28	0.6	21	0.7	17	0.7	13	0.7	11	0.8	9	0.9	7	0.9
30	69	0.5	45	0.6	33	0.6	25	0.7	20	0.7	16	0.7	13	0.8	10	0.9	8	0.9
35	80	0.5	52	0.6	38	0.6	29	0.7	23	0.7	19	0.7	15	0.8	12	0.9	10	0.9
40	91	0.5	59	0.6	44	0.6	33	0.7	26	0.7	21	0.7	17	0.8	14	0.9	11	0.9
45	102	0.5	67	0.6	49	0.6	37	0.7	30	0.7	24	0.7	19	0.8	16	0.9	13	0.9
50	113	0.5	74	0.6	54	0.6	42	0.7	33	0.7	26	0.7	22	0.8	17	0.9	14	0.9
55	123	0.5	81	0.6	60	0.6	46	0.7	36	0.7	29	0.7	24	0.8	19	0.8	15	0.9
60	134	0.5	88	0.6	65	0.6	50	0.7	39	0.7	32	0.7	26	0.8	21	0.8	17	0.9
65	145	0.5	95	0.6	70	0.6	54	0.7	42	0.7	34	0.7	28	0.8	22	0.9	18	0.9
70	155	0.5	102	0.6	75	0.6	58	0.7	45	0.7	37	0.7	30	0.8	24	0.9	19	0.9
75	166	0.5	109	0.6	81	0.6	62	0.7	49	0.7	39	0.7	32	0.8	26	0.8	21	0.9
80	176	0.5	116	0.6	86	0.6	65	0.7	52	0.7	42	0.7	34	0.8	27	0.9	22	0.9
90	198	0.5	130	0.6	96	0.6	73	0.7	58	0.7	47	0.7	38	0.8	31	0.8	25	0.9
100	219	0.5	144	0.6	107	0.6	81	0.7	64	0.7	52	0.7	42	0.8	34	0.9	28	0.9
110	240	0.5	158	0.6	117	0.6	89	0.7	71	0.7	57	0.7	47	0.8	37	0.8	30	0.9
120	261	0.5	172	0.6	127	0.6	97	0.7	77	0.7	62	0.7	51	0.8	41	0.8	33	0.9
130	282	0.5	185	0.6	138	0.6	105	0.7	83	0.7	67	0.7	55	0.8	44	0.8	36	0.9
140	302	0.5	199	0.6	148	0.6	113	0.7	89	0.7	72	0.7	59	0.8	47	0.8	38	0.9
150	323	0.5	213	0.6	158	0.6	121	0.7	96	0.7	77	0.7	63	0.8	50	0.8	41	0.9
160	343	0.5	226	0.6	168	0.6	129	0.7	102	0.7	82	0.7	67	0.8	54	0.9	44	0.9
170	363	0.5	240	0.6	178	0.6	136	0.7	108	0.7	87	0.7	71	0.8	57	0.8	46	0.9
180	383	0.5	253	0.6	188	0.6	144	0.7	114	0.7	92	0.7	75	0.8	60	0.9	49	0.9

Q = Flow in Cubic Feet per Second, V = Velocity in Feet per Second, T = Top Width in Feet
D = Depth in Feet

Parabolic Waterway Design

Grade 8.0 Percent

Q cfs	V = 2.0 T	V = 2.0 D	V = 2.5 T	V = 2.5 D	V = 3.0 T	V = 3.0 D	V = 3.5 T	V = 3.5 D	V = 4.0 T	V = 4.0 D	V = 4.5 T	V = 4.5 D	V = 5.0 T	V = 5.0 D	V = 5.5 T	V = 5.5 D	V = 6.0 T	V = 6.0 D
15	37	0.5	27	0.5	19	0.5	15	0.6	12	0.6	9	0.7	8	0.7	6	0.7	5	0.8
20	49	0.5	35	0.5	25	0.5	20	0.6	16	0.6	13	0.7	10	0.7	9	0.7	7	0.8
25	61	0.5	44	0.5	31	0.5	25	0.6	19	0.6	16	0.7	13	0.7	11	0.7	9	0.8
30	73	0.5	53	0.5	37	0.5	30	0.6	23	0.6	19	0.7	16	0.7	13	0.7	11	0.8
35	85	0.5	61	0.5	43	0.5	35	0.6	27	0.6	22	0.6	18	0.7	15	0.7	12	0.8
40	97	0.5	70	0.5	49	0.5	40	0.6	31	0.6	25	0.6	21	0.7	17	0.7	14	0.8
45	109	0.5	78	0.5	55	0.5	45	0.6	35	0.6	28	0.6	23	0.7	19	0.7	16	0.8
50	120	0.5	87	0.5	61	0.5	50	0.6	38	0.6	31	0.7	26	0.7	21	0.7	17	0.8
55	132	0.5	95	0.5	67	0.5	55	0.6	42	0.6	34	0.7	28	0.7	23	0.7	19	0.8
60	143	0.5	103	0.5	73	0.5	60	0.6	46	0.6	37	0.7	31	0.7	25	0.7	21	0.8
65	155	0.5	111	0.5	79	0.5	65	0.6	50	0.6	40	0.7	33	0.7	27	0.7	23	0.8
70	166	0.5	120	0.5	85	0.5	69	0.6	53	0.6	43	0.6	36	0.7	29	0.7	24	0.8
75	177	0.5	128	0.5	91	0.5	74	0.6	57	0.6	46	0.7	38	0.7	31	0.7	26	0.8
80	188	0.5	136	0.5	96	0.5	79	0.6	61	0.6	49	0.6	41	0.7	33	0.7	28	0.8
90	211	0.5	152	0.5	108	0.6	88	0.6	68	0.6	55	0.7	46	0.7	37	0.7	31	0.8
100	234	0.5	168	0.5	120	0.6	98	0.6	75	0.6	61	0.7	51	0.7	41	0.7	34	0.8
110	256	0.5	185	0.5	131	0.6	108	0.6	83	0.6	67	0.7	57	0.7	46	0.7	38	0.8
120	278	0.5	201	0.5	143	0.6	117	0.6	90	0.6	73	0.7	61	0.7	50	0.7	41	0.8
130	300	0.5	217	0.5	154	0.6	126	0.6	97	0.6	78	0.7	65	0.7	54	0.7	44	0.8
140	322	0.5	233	0.5	166	0.6	136	0.6	104	0.6	84	0.7	70	0.7	58	0.7	48	0.8
150	344	0.5	248	0.5	177	0.6	145	0.6	112	0.6	90	0.7	75	0.7	62	0.7	51	0.8
160	366	0.5	264	0.5	188	0.6	154	0.6	119	0.6	96	0.7	80	0.7	66	0.7	54	0.8
170	387	0.5	280	0.5	199	0.6	164	0.6	126	0.6	102	0.7	85	0.7	70	0.7	58	0.8
180	408	0.5	295	0.5	210	0.6	173	0.6	133	0.6	107	0.7	90	0.7	74	0.7	61	0.8

Q = Flow in Cubic Feet per Second, V = Velocity in Feet per Second, T = Top Width in Feet
D = Depth in Feet

V for Retardance "D",
T and D for Retardance "C"

Parabolic Waterway Design

Grade 10.0 Percent

Q cfs	V = 2.0		V = 2.5		V = 3.0		V = 3.5		V = 4.0		V = 4.5		V = 5.0		V = 5.5		V = 6.0	
	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D
15	45	0.4	33	0.5	23	0.5	17	0.5	13	0.6	11	0.6	9	0.6	7	0.7	6	0.7
20	60	0.4	43	0.5	30	0.5	22	0.5	18	0.6	14	0.6	12	0.6	10	0.7	8	0.7
25	75	0.4	54	0.5	38	0.5	28	0.5	22	0.6	18	0.6	15	0.6	12	0.7	10	0.7
30	89	0.4	64	0.5	45	0.5	33	0.5	27	0.6	21	0.6	18	0.6	15	0.6	12	0.7
35	104	0.4	75	0.5	53	0.5	38	0.5	31	0.6	25	0.6	21	0.6	17	0.7	14	0.7
40	118	0.4	85	0.5	60	0.5	44	0.5	35	0.6	28	0.6	24	0.6	20	0.7	16	0.7
45	132	0.4	95	0.5	67	0.5	49	0.5	40	0.6	32	0.6	27	0.6	22	0.7	18	0.7
50	146	0.4	105	0.5	74	0.5	54	0.5	44	0.6	35	0.6	30	0.6	24	0.7	20	0.7
55	160	0.4	115	0.5	82	0.5	60	0.5	48	0.6	39	0.6	32	0.6	27	0.6	22	0.7
60	174	0.4	125	0.5	87	0.5	65	0.5	52	0.6	42	0.6	35	0.6	29	0.7	24	0.7
65	188	0.4	135	0.5	96	0.5	70	0.5	57	0.6	45	0.6	38	0.6	32	0.7	26	0.7
70	201	0.4	145	0.5	103	0.5	75	0.5	61	0.6	49	0.6	41	0.6	34	0.7	28	0.7
75	215	0.4	155	0.5	110	0.5	80	0.5	65	0.6	52	0.6	44	0.6	36	0.7	30	0.7
80	228	0.4	164	0.5	116	0.5	85	0.5	69	0.6	55	0.6	47	0.6	39	0.7	32	0.7
90	255	0.4	184	0.5	131	0.5	96	0.5	76	0.6	62	0.6	52	0.6	43	0.7	36	0.7
100	282	0.4	204	0.5	145	0.5	106	0.5	86	0.6	69	0.6	58	0.6	48	0.7	40	0.7
110	309	0.4	223	0.5	158	0.5	116	0.5	94	0.6	76	0.6	64	0.6	53	0.7	44	0.7
120	336	0.4	242	0.5	172	0.5	126	0.5	103	0.6	82	0.6	69	0.6	57	0.7	48	0.7
130	362	0.4	262	0.5	186	0.5	137	0.5	111	0.6	89	0.6	75	0.6	62	0.7	52	0.7
140	388	0.4	281	0.5	200	0.5	147	0.5	119	0.6	95	0.6	81	0.6	67	0.7	56	0.7
150	414	0.4	299	0.5	213	0.5	157	0.5	127	0.6	102	0.6	86	0.6	71	0.7	60	0.7
160	440	0.4	318	0.5	227	0.5	166	0.5	135	0.6	108	0.6	92	0.6	76	0.7	64	0.7
170	466	0.4	337	0.5	240	0.5	176	0.5	143	0.6	115	0.6	97	0.6	80	0.7	67	0.7
180	491	0.4	355	0.5	253	0.5	186	0.5	151	0.6	121	0.6	103	0.6	85	0.7	71	0.7

Q = Flow in Cubic Feet per Second, V = Velocity in Feet per Second, T = Top Width in Feet
D = Depth in Feet

Trapezoidal Channel Design

"C" Retardance   Grade 0.5 Percent   Side Slope - 2:1

Q cfs	Bottom Width, b, in Feet															
	b = 2		b = 4		b = 6		b = 8		b = 10		b = 12		b = 14		b = 16	
	D	V	D	V	D	V	D	V	D	V	D	V	D	V	D	V
15	2.1	1.1	1.8	1.1	1.6	1.0	1.5	1.0	1.3	0.9	1.3	0.8	1.2	0.8	1.2	0.7
20	2.3	1.3	1.9	1.3	1.7	1.2	1.5	1.2	1.4	1.1	1.4	1.0	1.3	0.9	1.2	0.9
25	2.4	1.5	2.1	1.5	1.8	1.4	1.7	1.3	1.5	1.2	1.4	1.2	1.4	1.1	1.3	1.0
30	2.5	1.7	2.2	1.6	1.9	1.6	1.7	1.5	1.6	1.4	1.5	1.3	1.4	1.2	1.4	1.2
35	2.7	1.8	2.3	1.8	2.0	1.7	1.8	1.6	1.7	1.5	1.6	1.5	1.5	1.4	1.4	1.3
40	2.8	1.9	2.4	1.9	2.1	1.8	1.9	1.8	1.8	1.7	1.7	1.6	1.6	1.5	1.5	1.4
45	2.9	2.0	2.5	2.0	2.2	1.9	2.0	1.9	1.8	1.8	1.7	1.7	1.6	1.6	1.6	1.5
50	2.9	2.1	2.6	2.1	2.3	2.1	2.1	2.0	1.9	1.9	1.8	1.8	1.7	1.7	1.6	1.6
55	3.0	2.2	2.7	2.2	2.4	2.2	2.2	2.1	2.0	2.0	1.9	1.9	1.8	1.8	1.7	1.7
60	3.1	2.3	2.8	2.3	2.5	2.2	2.2	2.2	2.0	2.1	1.9	2.0	1.8	1.9	1.7	1.8
65	3.2	2.4	2.8	2.4	2.5	2.3	2.3	2.2	2.1	2.2	2.0	2.1	1.9	2.0	1.8	1.9
70	3.3	2.5	2.9	2.4	2.6	2.4	2.4	2.3	2.2	2.2	2.0	2.2	1.9	2.1	1.8	2.0
75	3.4	2.5	3.0	2.5	2.7	2.5	2.4	2.4	2.2	2.3	2.1	2.2	1.9	2.1	1.8	2.1
80	3.4	2.6	3.1	2.6	2.7	2.5	2.5	2.5	2.3	2.4	2.1	2.3	2.0	2.2	1.9	2.1
90	3.6	2.7	3.2	2.7	2.9	2.7	2.6	2.6	2.4	2.5	2.2	2.4	2.1	2.3	2.0	2.3
100	3.7	2.8	3.3	2.8	3.0	2.8	2.7	2.7	2.5	2.7	2.3	2.6	2.2	2.5	2.1	2.4
110	3.9	2.9	3.5	2.9	3.1	2.9	2.8	2.8	2.6	2.8	2.4	2.7	2.3	2.6	2.2	2.5
120	4.0	3.1	3.5	3.0	3.2	3.0	2.9	3.0	2.7	2.9	2.5	2.8	2.4	2.7	2.2	2.6
130	4.1	3.1	3.7	3.1	3.3	3.1	3.0	3.0	2.8	3.0	2.6	2.9	2.5	2.8	2.3	2.7
140	4.2	3.2	3.8	3.2	3.4	3.2	3.1	3.1	2.9	3.1	2.7	3.0	2.5	2.9	2.4	2.8
150	4.3	3.3	3.9	3.3	3.5	3.3	3.2	3.2	3.0	3.1	2.8	3.1	2.6	3.0	2.5	2.9
160	4.4	3.4	4.0	3.4	3.6	3.4	3.3	3.3	3.1	3.2	2.9	3.2	2.7	3.1	2.5	3.0
170	4.5	3.5	4.1	3.5	3.7	3.4	3.4	3.4	3.1	3.3	2.9	3.2	2.8	3.2	2.6	3.1
180	4.6	3.6	4.1	3.6	3.8	3.5	3.5	3.5	3.2	3.4	3.0	3.3	2.8	3.2	2.7	3.2
190	4.6	3.6	4.[illegible]	3.6	3.9	3.6	3.6	3.5	3.3	3.5	3.1	3.4	2.9	3.3	2.7	3.2
200	4.7	3.7	4.3	3.7	3.9	3.7	3.6	3.6	3.4	3.5	3.2	3.5	3.0	3.4	2.8	3.3
220	4.9	3.8	4.5	3.8	4.1	3.8	3.8	3.7	3.5	3.7	3.3	3.6	3.1	3.5	2.9	3.4
240	5.0	3.9	4.6	3.9	4.2	3.9	3.9	3.8	3.6	3.8	3.4	3.7	3.2	3.6	3.0	3.6
260	5.2	4.0	4.8	4.0	4.4	4.0	4.1	4.0	3.8	3.9	3.5	3.8	3.3	3.8	3.2	3.7
280	5.3	4.1	4.9	4.1	4.5	4.1	4.2	4.1	3.9	4.0	3.7	4.0	3.6	3.9	3.3	3.8
300	5.5	4.2	5.0	4.2	4.7	4.2	4.3	4.2	4.0	4.1	3.8	4.1	3.6	4.0	3.4	3.9

Q = Flow, Cubic Feet per Second, V = Velocity, Feet per Second, b = Bottom Width, Feet, D = Depth, Feet.

USDA-SCS-Md   July 1975

Trapezoidal Channel Design

"C" Retardance Grade 0.5 Percent Side Slope = 2:1

Bottom Width, b, in Feet

Q cfs	b = 2		b = 4		b = 6		b = 8		b = 10		b = 12		b = 14		b = 16	
	D	V	D	V	D	V	D	V	D	V	D	V	D	V	D	V
15	1.7	1.6	1.5	1.5	1.3	1.4	1.1	1.3	1.1	1.1	1.0	1.0	1.0	1.0	0.9	0.9
20	1.9	1.8	1.6	1.8	1.4	1.7	1.2	1.5	1.1	1.4	1.1	1.3	1.0	1.2	1.0	1.1
25	2.0	2.1	1.7	2.0	1.5	1.9	1.3	1.8	1.2	1.6	1.2	1.5	1.1	1.4	1.0	1.3
30	2.1	2.3	1.8	2.2	1.6	2.1	1.4	1.9	1.3	1.8	1.2	1.7	1.2	1.6	1.1	1.5
35	2.2	2.5	1.9	2.4	1.6	2.3	1.5	2.1	1.4	2.0	1.3	1.9	1.2	1.8	1.2	1.7
40	2.3	2.6	2.0	2.5	1.7	2.5	1.6	2.3	1.4	2.2	1.3	2.0	1.3	1.9	1.2	1.8
45	2.4	2.8	2.0	2.7	1.8	2.6	1.6	2.5	1.5	2.3	1.4	2.2	1.3	2.1	1.2	2.0
50	2.5	2.9	2.1	2.8	1.9	2.7	1.7	2.6	1.5	2.5	1.4	2.3	1.4	2.2	1.3	2.1
55	2.6	3.0	2.2	2.9	1.9	2.9	1.8	2.7	1.6	2.6	1.5	2.5	1.4	2.3	1.3	2.2
60	2.6	3.1	2.3	3.1	2.0	2.9	1.8	2.9	1.7	2.7	1.5	2.6	1.5	2.4	1.4	2.3
65	2.7	3.2	2.4	3.1	2.1	3.1	1.9	2.9	1.7	2.8	1.6	2.7	1.5	2.6	1.4	2.4
70	2.8	3.3	2.4	3.3	2.1	3.2	2.0	3.1	1.8	2.9	1.6	2.8	1.5	2.7	1.5	2.6
75	2.8	3.4	2.5	3.4	2.2	3.3	2.0	3.1	1.8	3.0	1.7	2.9	1.6	2.8	1.5	2.7
80	2.9	3.5	2.5	3.4	2.3	3.4	2.0	3.3	1.9	3.1	1.7	3.0	1.7	2.9	1.5	2.7
90	3.0	3.6	2.7	3.6	2.4	3.5	2.1	3.4	2.0	3.3	1.8	3.2	1.7	3.0	1.6	2.9
100	3.1	3.8	2.8	3.8	2.5	3.7	2.2	3.6	2.1	3.5	1.9	3.3	1.8	3.2	1.7	3.1
110	3.3	4.0	2.9	3.9	2.6	3.8	2.3	3.7	2.1	3.6	2.0	3.5	1.9	3.3	1.8	3.2
120	3.4	4.1	3.0	4.0	2.7	4.0	2.4	3.9	2.2	3.7	2.1	3.6	1.9	3.5	1.8	3.4
130	3.5	4.2	3.1	4.1	2.8	4.1	2.5	4.0	2.3	3.9	2.1	3.7	2.0	3.6	1.9	3.5
140	3.6	4.3	3.2	4.3	2.8	4.2	2.6	4.1	2.4	4.0	2.2	3.9	2.1	3.8	1.9	3.6
150	3.7	4.4	3.3	4.4	2.9	4.3	2.7	4.2	2.4	4.1	2.3	4.0	2.1	3.9	2.0	3.7
160	3.7	4.5	3.3	4.5	3.0	4.4	2.7	4.4	2.5	4.2	2.3	4.1	2.2	4.0	2.1	3.9
170	3.8	4.6	3.4	4.6	3.1	4.5	2.8	4.4	2.6	4.3	2.4	4.2	2.2	4.1	2.1	4.0
180	3.9	4.7	3.5	4.7	3.1	4.6	2.9	4.5	2.7	4.4	2.5	4.3	2.3	4.2	2.2	4.1
190	4.0	4.8	3.6	4.8	3.2	4.7	2.9	4.7	2.7	4.5	2.5	4.4	2.4	4.3	2.2	4.2
200	4.1	4.9	3.6	4.9	3.3	4.8	3.0	4.7	2.8	4.6	2.6	4.5	2.4	4.4	2.3	4.2
220	4.2	5.1	3.8	5.0	3.4	5.0	3.1	4.9	2.9	4.8	2.7	4.7	2.5	4.6	2.4	4.4
240	4.3	5.2	3.9	5.2	3.6	5.1	3.3	5.1	3.0	4.9	2.8	4.9	2.6	4.7	2.5	4.6
260	4.4	5.4	4.0	5.3	3.7	5.3	3.4	5.2	3.1	5.1	2.9	5.0	2.7	4.9	2.6	4.8
280	4.6	5.5	4.1	5.5	3.8	5.4	3.5	5.4	3.2	5.2	3.0	5.1	2.8	5.0	2.7	4.9
300	4.7	5.6	4.3	5.6	3.9	5.6	3.6	5.5	3.3	5.4	3.1	5.3	2.9	5.2	2.8	5.1

Q = Flow, Cubic Feet per Second, V = Velocity, Feet per Second, b = Bottom Width,Feet, D = Depth,Feet.

Trapezoidal Channel Design

"C" Retardance Grade 1.0 Percent Side Slope 2:1

Bottom Width, b, in Feet

Q cfs	b = 2 D	b = 2 V	b = 4 D	b = 4 V	b = 6 D	b = 6 V	b = 8 D	b = 8 V	b = 10 D	b = 10 V	b = 12 D	b = 12 V	b = 14 D	b = 14 V	b = 16 D	b = 16 V
15	1.4	2.2	1.2	2.0	1.0	1.8	0.9	1.7	0.9	1.5	0.8	1.4	0.8	1.2	0.7	1.1
20	1.5	2.5	1.3	2.4	1.1	2.2	1.0	2.0	0.9	1.8	0.9	1.7	0.8	1.5	0.8	1.4
25	1.7	2.8	1.4	2.7	1.2	2.5	1.1	2.3	1.0	2.1	0.9	2.0	0.9	1.8	0.8	1.7
30	1.8	3.1	1.5	3.0	1.3	2.8	1.1	2.6	1.0	2.4	1.0	2.2	0.9	2.0	0.9	1.9
35	1.9	3.3	1.6	3.2	1.3	3.0	1.2	2.8	1.1	2.6	1.0	2.4	1.0	2.3	0.9	2.1
40	1.9	3.5	1.6	3.4	1.4	3.2	1.3	3.0	1.1	2.8	1.1	2.6	1.0	2.5	1.0	2.3
45	2.0	3.7	1.7	3.6	1.5	3.4	1.3	3.2	1.2	3.0	1.1	2.8	1.1	2.7	1.0	2.5
50	2.1	3.9	1.8	3.7	1.5	3.6	1.4	3.4	1.3	3.2	1.2	3.0	1.1	2.8	1.0	2.7
55	2.2	4.0	1.8	3.9	1.6	3.7	1.4	3.5	1.3	3.3	1.2	3.2	1.1	3.0	1.1	2.8
60	2.2	4.2	1.9	4.1	1.7	3.9	1.5	3.7	1.3	3.5	1.3	3.3	1.2	3.1	1.1	3.0
65	2.3	4.3	1.9	4.2	1.7	4.0	1.5	3.9	1.4	3.6	1.3	3.5	1.2	3.3	1.1	3.1
70	2.4	4.4	2.0	4.3	1.8	4.2	1.6	4.0	1.4	3.8	1.3	3.6	1.2	3.4	1.2	3.3
75	2.4	4.5	2.1	4.5	1.8	4.3	1.6	4.1	1.5	3.9	1.4	3.7	1.3	3.5	1.2	3.4
80	2.5	4.6	2.1	4.5	1.9	4.4	1.7	4.2	1.5	4.0	1.4	3.9	1.3	3.7	1.2	3.5
90	2.6	4.9	2.2	4.8	2.0	4.6	1.7	4.5	1.6	4.3	1.5	4.1	1.4	3.9	1.3	3.7
100	2.7	5.1	2.3	5.0	2.0	4.9	1.8	4.7	1.7	4.5	1.5	4.3	1.4	4.1	1.4	3.9
110	2.8	5.2	2.4	5.2	2.1	5.0	1.9	4.9	1.7	4.7	1.6	4.5	1.5	4.3	1.4	4.1
120	2.9	5.4	2.5	5.4	2.2	5.2	2.0	5.0	1.8	4.9	1.7	4.7	1.6	4.5	1.5	4.3
130	3.0	5.6	2.6	5.5	2.3	5.4	2.1	5.2	1.9	5.0	1.7	4.9	1.6	4.7	1.5	4.5
140	3.0	5.7	2.7	5.6	2.4	5.5	2.1	5.4	1.9	5.2	1.8	5.0	1.7	4.8	1.6	4.7
150	3.1	5.9	2.7	5.8	2.4	5.6	2.2	5.5	2.0	5.4	1.8	5.2	1.7	5.0	1.6	4.8
160	3.2	6.0	2.8	6.0	2.5	5.8	2.2	5.7	2.1	5.5	1.9	5.3	1.8	5.1	1.7	4.9
170					2.6	6.0	2.3	5.8	2.1	5.6	2.0	5.5	1.8	5.2	1.7	5.1
180							2.4	5.9	2.2	5.8	2.0	5.6	1.9	5.4	1.8	5.2
190									2.2	5.9	2.1	5.7	1.9	5.5	1.8	5.4
200									2.3	6.0	2.1	5.8	2.0	5.6	1.9	5.4
220													2.1	5.9	2.0	5.7
240															2.0	5.9

Q = Flow, Cubic Feet per Second, V = Velocity, Feet per Second, b = Bottom Width,Feet, D = Depth,Feet.

Trapezoidal Channel Design

"C" Retardance   Grade 2.0 Percent   Side Slope = 2:1

Bottom Width, b, in Feet

Q cfs	b = 2 D	b = 2 V	b = 4 D	b = 4 V	b = 6 D	b = 6 V	b = 8 D	b = 8 V	b = 10 D	b = 10 V	b = 12 D	b = 12 V	b = 14 D	b = 14 V	b = 16 D	b = 16 V
15	1.2	3.0	0.9	2.7	0.8	2.4	0.7	2.1	0.7	1.9	0.7	1.7	0.6	1.6	0.6	1.4
20	1.3	3.4	1.0	3.2	0.9	2.9	0.8	2.6	0.7	2.3	0.7	2.1	0.7	1.0	0.6	1.8
25	1.4	3.8	1.1	3.6	1.0	3.3	0.9	3.0	0.8	2.7	0.7	2.5	0.7	2.3	0.7	2.1
30	1.5	4.2	1.2	3.9	1.0	3.6	0.9	3.3	0.8	3.1	0.8	2.8	0.7	2.6	0.7	2.4
35	1.6	4.4	1.3	4.2	1.1	3.9	1.0	3.6	0.9	3.3	0.8	3.1	0.8	2.9	0.7	2.7
40	1.6	4.7	1.3	4.5	1.1	4.2	1.0	3.9	0.9	3.6	0.9	3.4	0.8	3.1	0.8	2.9
45	1.7	4.9	1.4	4.7	1.2	4.5	1.1	4.2	1.0	3.9	0.9	3.6	0.8	3.4	0.8	3.2
50	1.8	5.2	1.5	5.0	1.2	4.7	1.1	4.4	1.0	4.1	0.9	3.9	0.9	3.6	0.8	3.4
55	1.8	5.4	1.5	5.1	1.3	4.9	1.2	4.6	1.0	4.3	1.0	4.0	0.9	3.8	0.9	3.6
60	1.9	5.5	1.6	5.3	1.4	5.1	1.2	4.8	1.1	4.5	1.0	4.2	0.9	4.0	0.9	3.8
65	1.9	5.7	1.6	5.5	1.4	5.3	1.2	5.0	1.1	4.7	1.0	4.4	1.0	4.2	0.9	4.0
70	2.0	5.9	1.7	5.7	1.4	5.5	1.3	5.2	1.2	4.9	1.1	4.6	1.0	4.3	1.0	4.1
75			1.7	5.9	1.5	5.6	1.3	5.3	1.2	5.0	1.1	4.7	1.0	4.5	1.0	4.3
80					1.5	5.8	1.4	5.5	1.2	5.2	1.1	4.9	1.1	4.7	1.0	4.4
90							1.4	5.8	1.3	5.5	1.2	5.2	1.1	5.0	1.1	4.7
100									1.4	5.8	1.3	5.5	1.2	5.2	1.1	5.0
110									1.4	6.0	1.3	5.8	1.2	5.5	1.1	5.2
120											1.4	6.0	1.3	5.7	1.2	5.4
130													1.3	5.9	1.2	5.7
140															1.3	5.9

Q = Flow, Cubic Feet per Second, V = Velocity, Feet per Second, b = Bottom Width,Feet, D = Depth,Feet.

Trapezoidal Channel Design

"C" Retardance   Grade 3 Percent   Side Slope = 2:1

Bottom Width, b, in Feet

Q cfs	b = 2 D	b = 2 V	b = 4 D	b = 4 V	b = 6 D	b = 6 V	b = 8 D	b = 8 V	b = 10 D	b = 10 V	b = 12 D	b = 12 V	b = 14 D	b = 14 V	b = 16 D	b = 16 V
15	1.0	3.5	0.8	3.2	0.7	2.8	0.6	2.5	0.6	2.2	0.6	2.0	0.5	1.8	0.5	1.7
20	1.1	4.1	0.9	3.7	0.8	3.4	0.7	3.0	0.7	2.7	0.6	2.5	0.6	2.3	0.6	2.1
25	1.2	4.5	1.0	4.2	0.8	3.8	0.8	3.5	0.7	3.2	0.7	2.9	0.6	2.6	0.6	2.5
30	1.3	4.9	1.1	4.6	0.9	4.2	0.8	3.8	0.7	3.5	0.7	3.2	0.7	3.0	0.6	2.8
35	1.4	5.3	1.1	4.9	1.0	4.6	0.9	4.2	0.8	3.9	0.7	3.6	0.7	3.3	0.7	3.1
40	1.5	5.6	1.2	5.3	1.0	4.9	0.9	4.5	0.8	4.2	0.8	3.9	0.7	3.6	0.7	3.3
45	1.5	5.9	1.2	5.6	1.1	5.2	0.9	4.8	0.9	4.5	0.8	4.2	0.8	3.9	0.7	3.6
50			1.3	5.9	1.1	5.4	1.0	5.1	0.9	4.7	0.8	4.4	0.8	4.1	0.7	3.9
55					1.2	5.7	1.0	5.4	0.9	5.0	0.9	4.7	0.8	4.4	0.8	4.1
60					1.2	5.9	1.2	5.6	1.0	5.2	0.9	4.9	0.8	4.6	0.8	4.3
65							1.1	5.8	1.0	5.4	0.9	5.1	0.9	4.8	0.8	4.5
70							1.1	6.0	1.0	5.6	1.0	5.3	0.9	5.0	0.8	4.7
75									1.1	5.8	1.0	5.5	0.9	5.1	0.9	4.9
80											1.0	5.6	0.9	5.3	0.9	5.0
90													1.0	5.6	1.0	5.4
100													1.0	6.0	1.0	5.7
110															1.0	6.0

Q = Flow, Cubic Feet per Second, V = Velocity, Feet per Second, b = Bottom Width, Feet, D = Depth, Feet.

Trapezoidal Channel Design

"C" Retardance Grade 4 Percent Side Slope = 2:1

Bottom Width, b, in Feet

Q cfs	b = 2 D	b = 2 V	b = 4 D	b = 4 V	b = 6 D	b = 6 V	b = 8 D	b = 8 V	b = 10 D	b = 10 V	b = 12 D	b = 12 V	b = 14 D	b = 14 V	b = 16 D	b = 16 V
15	1.0	4.0	0.8	3.6	0.7	3.2	0.6	2.8	0.5	2.4	0.5	2.2	0.5	2.0	0.5	1.8
20	1.1	4.6	0.8	4.2	0.7	3.8	0.6	3.3	0.6	3.0	0.6	2.7	0.5	2.5	0.5	2.3
25	1.1	5.1	0.9	4.8	0.8	4.3	0.7	3.8	0.6	3.5	0.6	3.1	0.6	2.9	0.5	2.7
30	1.2	5.6	1.0	5.2	0.8	4.7	0.7	4.3	0.7	3.9	0.6	3.6	0.6	3.3	0.6	3.0
35	1.3	5.9	1.0	5.6	0.9	5.1	0.8	4.7	0.7	4.3	0.7	3.9	0.6	3.6	0.6	3.4
40			1.1	5.9	0.9	5.4	0.8	5.0	0.8	4.6	0.7	4.2	0.6	3.9	0.6	3.7
45					1.0	5.8	0.9	5.4	0.8	4.9	0.7	4.6	0.7	4.3	0.6	4.0
50							0.9	5.6	0.8	5.2	0.8	4.9	0.7	4.6	0.7	4.2
55							0.9	5.9	0.8	5.5	0.8	5.1	0.7	4.8	0.7	4.5
60									0.9	5.8	0.8	5.4	0.8	5.0	0.7	4.8
65									0.9	6.0	0.8	5.6	0.8	5.3	0.7	5.0
70											0.9	5.9	0.9	5.5	0.8	5.2
75													0.9	5.7	0.8	5.4
80													0.9	5.9	0.8	5.6
90															0.9	5.9

Q = Flow, Cubic Feet per Second, V = Velocity, Feet per Second, b = Bottom Width, Feet, D = Depth, Feet.

Trapezoidal Channel Design

"C" Retardance Grade 5 Percent Side Slope 2:1

Bottom Width, b, in Feet

Q cfs	b = 2 D	b = 2 V	b = 4 D	b = 4 V	b = 6 D	b = 6 V	b = 8 D	b = 8 V	b = 10 D	b = 10 V	b = 12 D	b = 12 V	b = 14 D	b = 14 V	b = 16 D	b = 16 V
15	0.9	4.4	0.7	3.9	0.6	3.4	0.6	3.0	0.5	2.6	0.5	2.3	0.5	2.1	0.5	2.0
20	1.0	5.1	0.8	4.6	0.7	4.1	0.6	3.6	0.6	3.2	0.5	2.9	0.5	2.7	0.5	2.4
25	1.1	5.6	0.9	5.2	0.7	4.6	0.6	4.2	0.6	3.7	0.6	3.4	0.5	3.1	0.5	2.9
30			0.9	5.6	0.8	5.1	0.7	4.6	0.6	4.2	0.6	3.9	0.6	3.5	0.5	3.3
35					0.8	5.5	0.7	5.1	0.7	4.6	0.6	4.2	0.6	3.9	0.6	3.6
40					0.9	5.9	0.8	5.4	0.7	5.0	0.7	4.6	0.6	4.3	0.6	4.0
45							0.8	5.7	0.7	5.3	0.7	5.0	0.6	4.6	0.6	4.3
50									0.8	5.6	0.7	5.3	0.7	4.9	0.6	4.6
55									0.9	6.0	0.7	5.5	0.7	5.2	0.7	4.9
60											0.8	5.8	0.7	5.4	0.7	5.1
65													0.7	5.7	0.7	5.3
70													0.8	5.9	0.7	5.6
75															0.7	5.8
80															0.8	6.0

Grade 6 Percent

Q cfs	b = 2 D	b = 2 V	b = 4 D	b = 4 V	b = 6 D	b = 6 V	b = 8 D	b = 8 V	b = 10 D	b = 10 V	b = 12 D	b = 12 V	b = 14 D	b = 14 V	b = 16 D	b = 16 V
15	0.9	4.8	0.7	4.2	0.6	3.6	0.5	3.2	0.5	2.8	0.5	2.5	0.4	2.3	0.4	2.1
20	0.9	5.4	0.7	4.9	0.6	4.4	0.6	3.8	0.5	3.4	0.5	3.1	0.5	2.8	0.5	2.6
25			0.8	5.6	0.7	4.9	0.6	4.4	0.6	4.0	0.5	3.6	0.5	3.3	0.5	3.1
30					0.7	5.5	0.7	4.9	0.6	4.5	0.6	4.1	0.5	3.7	0.5	3.5
35					0.8	5.9	0.7	5.4	0.6	4.9	0.6	4.5	0.6	4.2	0.5	3.8
40							0.7	5.8	0.7	5.3	0.6	4.9	0.7	4.5	0.6	4.2
45									0.7	5.6	0.6	5.2	0.6	4.9	0.6	4.6
50											0.7	5.6	0.6	5.2	0.6	4.9
55											0.7	5.8	0.7	5.5	0.6	5.1
60													0.7	5.8	0.6	5.4
65															0.7	5.7
70															0.7	5.9

Q = Flow, Cubic Feet per Second, V = Velocity, Feet per Second, b = Bottom Width, Feet, D = Depth, Feet.

Trapezoidal Channel Design

"C" Retardance   Grade 8 Percent   Side Slope = 2:1

Bottom Width, b, in Feet

Q cfs	b = 2 D	b = 2 V	b = 4 D	b = 4 V	b = 6 D	b = 6 V	b = 8 D	b = 8 V	b = 10 D	b = 10 V	b = 12 D	b = 12 V	b = 14 D	b = 14 V	b = 16 D	b = 16 V
15	0.8	5.3	0.6	4.7	0.5	4.1	0.5	3.5	0.4	3.1	0.4	2.8	0.4	2.5	0.4	2.3
20			0.7	5.5	0.6	4.8	0.5	4.2	0.5	3.8	0.5	3.4	0.4	3.1	0.4	2.8
25					0.6	5.5	0.6	4.9	0.5	4.4	0.5	4.0	0.5	3.6	0.4	3.3
30							0.6	5.5	0.5	4.9	0.5	4.5	0.5	4.2	0.5	3.8
35							0.6	6.0	0.6	5.5	0.5	5.0	0.5	4.6	0.5	4.2
40									0.6	5.9	0.6	5.4	0.5	5.0	0.5	4.6
45											0.6	5.7	0.6	5.4	0.5	5.0
50													0.6	5.7	0.5	5.3
55															0.6	5.7
60															0.6	6.0

Grade 10 Percent

Q cfs	b = 2 D	b = 2 V	b = 4 D	b = 4 V	b = 6 D	b = 6 V	b = 8 D	b = 8 V	b = 10 D	b = 10 V	b = 12 D	b = 12 V	b = 14 D	b = 14 V	b = 16 D	b = 16 V
15	0.7	5.9	0.6	5.1	0.5	4.4	0.4	3.8	0.4	3.4	0.4	3.0	0.4	2.6	0.4	2.4
20			0.6	6.0	0.5	5.2	0.5	4.6	0.4	4.1	0.4	3.7	0.4	3.4	0.4	3.1
25					0.6	6.0	0.5	5.3	0.5	4.7	0.4	4.3	0.4	3.9	0.4	3.6
30							0.6	5.9	0.5	5.3	0.5	4.9	0.5	4.4	0.4	4.1
35									0.5	5.8	0.5	5.4	0.5	4.9	0.5	4.6
40											0.5	5.8	0.5	5.3	0.5	5.0
45													0.5	5.7	0.5	5.4
50															0.5	5.7

Q = Flow, Cubic Feet per Second, V = Velocity, Feet per Second, b = Bottom Width, Feet, D = Depth, Feet.

APPENDIX D*

Sample Design Procedure for Riprap-Lined Channels

This design of riprap-lined channels is from the National Cooperative Highway Research Program Report No. 108, entitled "Tentative Design Procedure for Riprap-Lined Channels." It is based on the tractive force method and covers the design of riprap in two basic channel shapes, trapezoidal and triangular. (19)

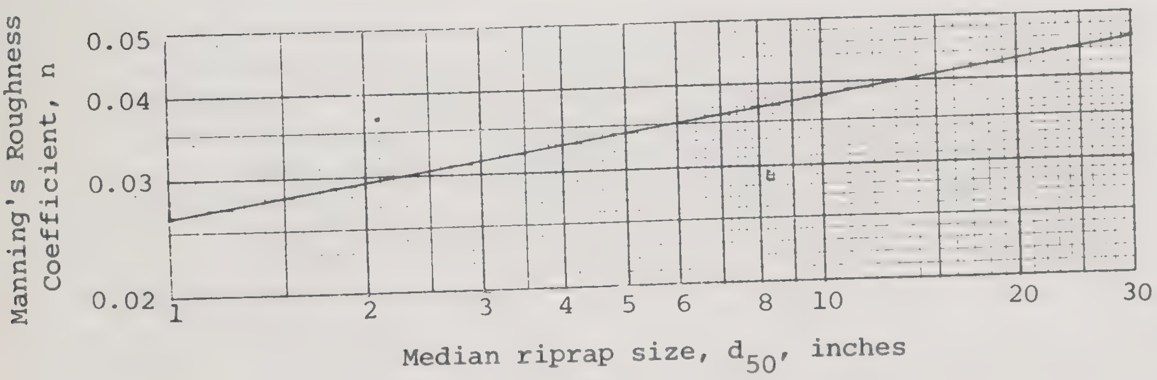
NOTE: This procedure is for the uniform flow in channels and is not to be used for design of riprap deenergizing devices immediately downstream from such high velocity devices as pipes and culverts. See the Standard and Specification for Storm Drain Outlet Protection.

The method in Report No. 108 (design procedure beginning on p. 18) gives a simple and direct solution to the design of trapezoidal channels including channel carrying capacity, channel geometry and the riprap lining. The publication is a very good reference and design aid.

The procedure presented in this Appendix is based on the assumption that the channel is already designed and the remaining problem is to determine the riprap size that would be stable in the channel. The designer would first determine the channel dimensions by the use of Manning's equation. The n value for use in Manning's equation is estimated by estimating a riprap size and then determining the corresponding n value for the riprapped channel from Curve 1, below.

Curve 1 - Manning's "n" for Riprap-Lined Channels

$$n = 0.0395(d_{50})^{1/6}$$



*from USDA, Soil Conservation Service, College Park, Maryland. Standards and Specifications for Soil Erosion and Sediment Control in Developing Areas. July 1975.

When the channel dimensions are known the riprap can be designed (or an already completed design may be checked) as follows:

Trapezoidal Channels

1. Calculate the b/d ratio and enter curve 2 to find the P/R ratio.

2. Enter curve 3 with S_b, Q, and P/R to find median riprap diameter, d_{50}, for straight channels.

3. Enter curve 1 to find the actual n value corresponding to the d_{50} from step 2. If the estimated and actual n values are not in reasonable agreement another trial must be made.

4. For channels with bends, calculate the ratio B_s/R_o, where B_s is the channel surface width and R_o is the radius of the bend. Enter curve 4 and find the bend factor, F_B. Multiply the d_{50} for straight channels by the bend factor to determine riprap size to be used in bends. If the d_{50} for the bend is less than 1.1 times the d_{50} for the straight channel, then the size for straight channel may be used in the bend, otherwise the larger stone size calculated for the bend shall be used. The riprap shall extend across the full channel section and shall extend upstream and downstream from the ends of the curve a distance equal to five times the bottom width.

5. Enter curve 5 to determine maximum stable side slope of riprap surface.

Triangular Channels

1. Enter curve 3A with S_b, Q and Z and find the median riprap diameter, d_{50}, for straight channels.

2. Enter curve 1 to find the actual n value. If the estimated and actual n values are not in reasonable agreement another trial must be made.

3. For channels with bends, see step 4 under Trapezoidal channels.

The riprap size to be specified on the plans shall be the maximum stone size in the mixture which shall be 1.5 times the d_{50}. The thickness of the riprap layer is 1.5 times the maximum stone size, but not less than six inches. Freeboard shall be added to the channel depth and shall be not less than 0.2 times the depth of flow or 0.3 feet, whichever is greater.

Example:

Given:

Trapezoidal channel

$Q = 100$ cfs
$S = 0.01$ ft/ft.
Side slopes = 2.5:1
Mean bend radius, $R_o = 25'$
$n = .033$ (estimated and used to design the channel to find that $b = 6'$ and $d = 1.8'$)
Type of rock available is crushed stone.

Solution:

<u>Straight channel reach</u>

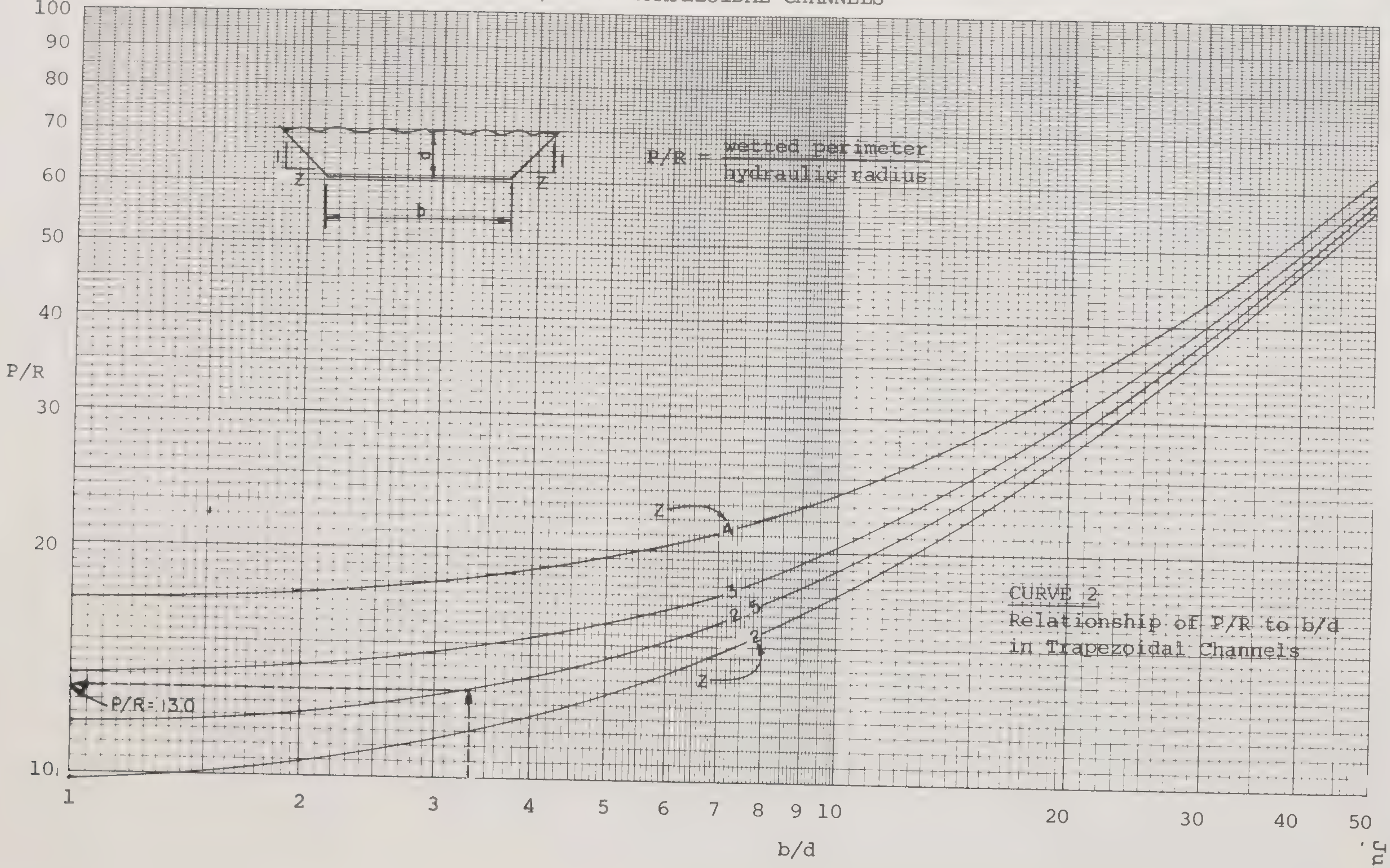
$b/d = 6/1.8 = 3.33$
from curve 2, $P/R = 13.0$
from curve 3, $d_{50} = 3.4"$
from curve 1, n (actual) = 0.032, which is reasonably close to the estimated n of 0.033.
Maximum riprap size = 1.5 x 3.4 = 5.1"
Riprap thickness = 1.5 x 5.1 = 7.7"
<u>Use 5" as maximum riprap size and 8" as riprap layer thickness.</u>

<u>Channel bend</u>

$B_s = b + 2zd = 6 + (2)(2.5)(1.8) = 15'$
$B_s/R_o = 12/25 = 0.60$
from curve 4, $F_B = 1.33$
$F_B = 1.33 > 1.1$, therefore the bend factor must be used.
Riprap size in bend, $d_{50} = 3.4 \times 1.33 = 4.52"$
Max. riprap size in bend = 4.52 x 1.5 = 6.78"
Riprap thickness = 10.2"
<u>Use 7" for max. riprap size and 10" for riprap layer thickness.</u>
The heavier riprap for the bend shall extend upstream and downstream from the ends of the bend a distance of (5)(6) = 30 feet.
From curve 5, it can be found that the riprap for $d_{50} = 3.4"$ and 4.52" will both be stable on a 2.5:1 side slope.

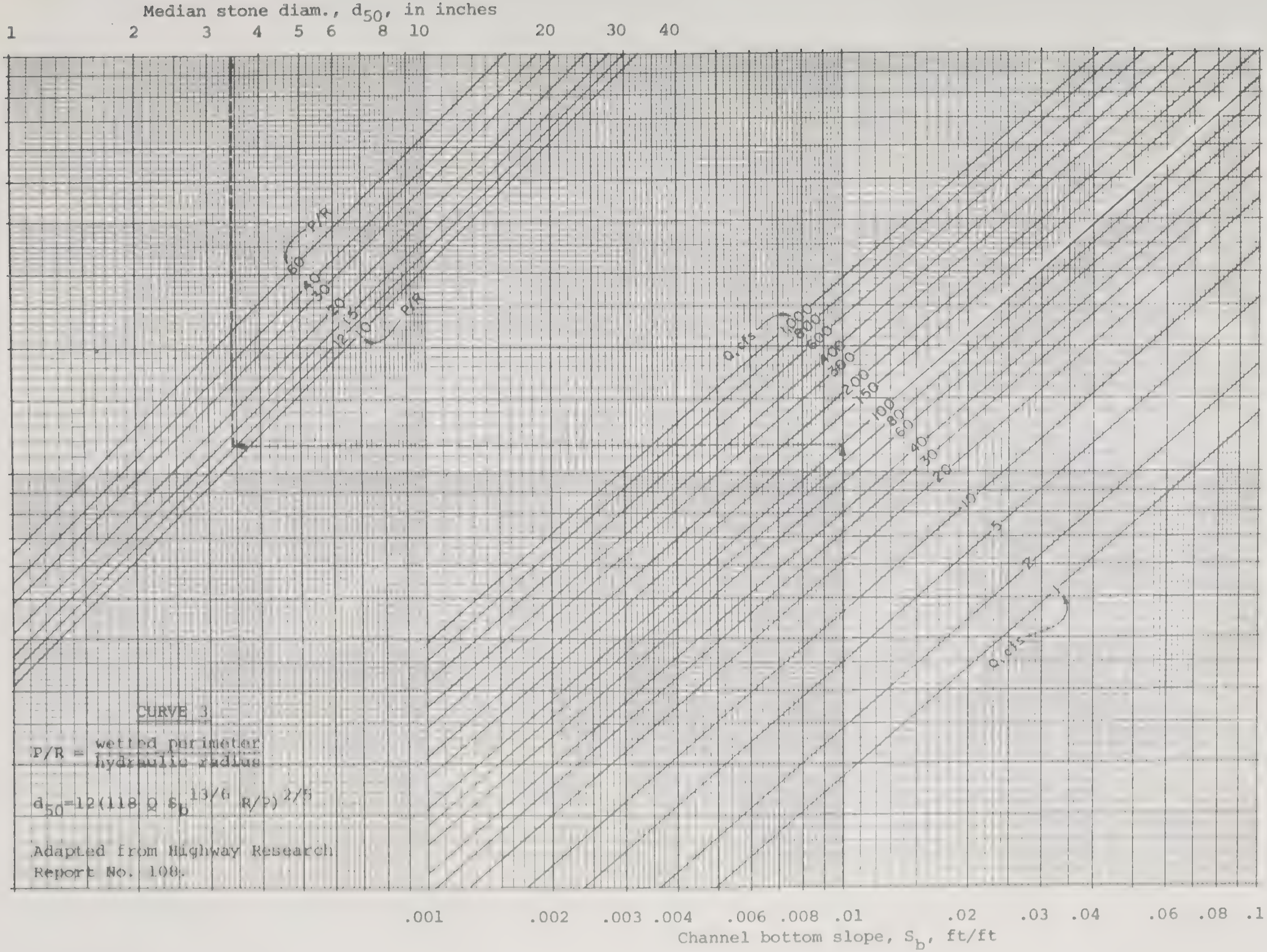
Freeboard = (0.2)(1.8) = .36' but not less than 0.3'
Therefore, minimum freeboard is 0.36'. <u>Use 0.4'</u>

P/R FOR TRAPEZOIDAL CHANNELS

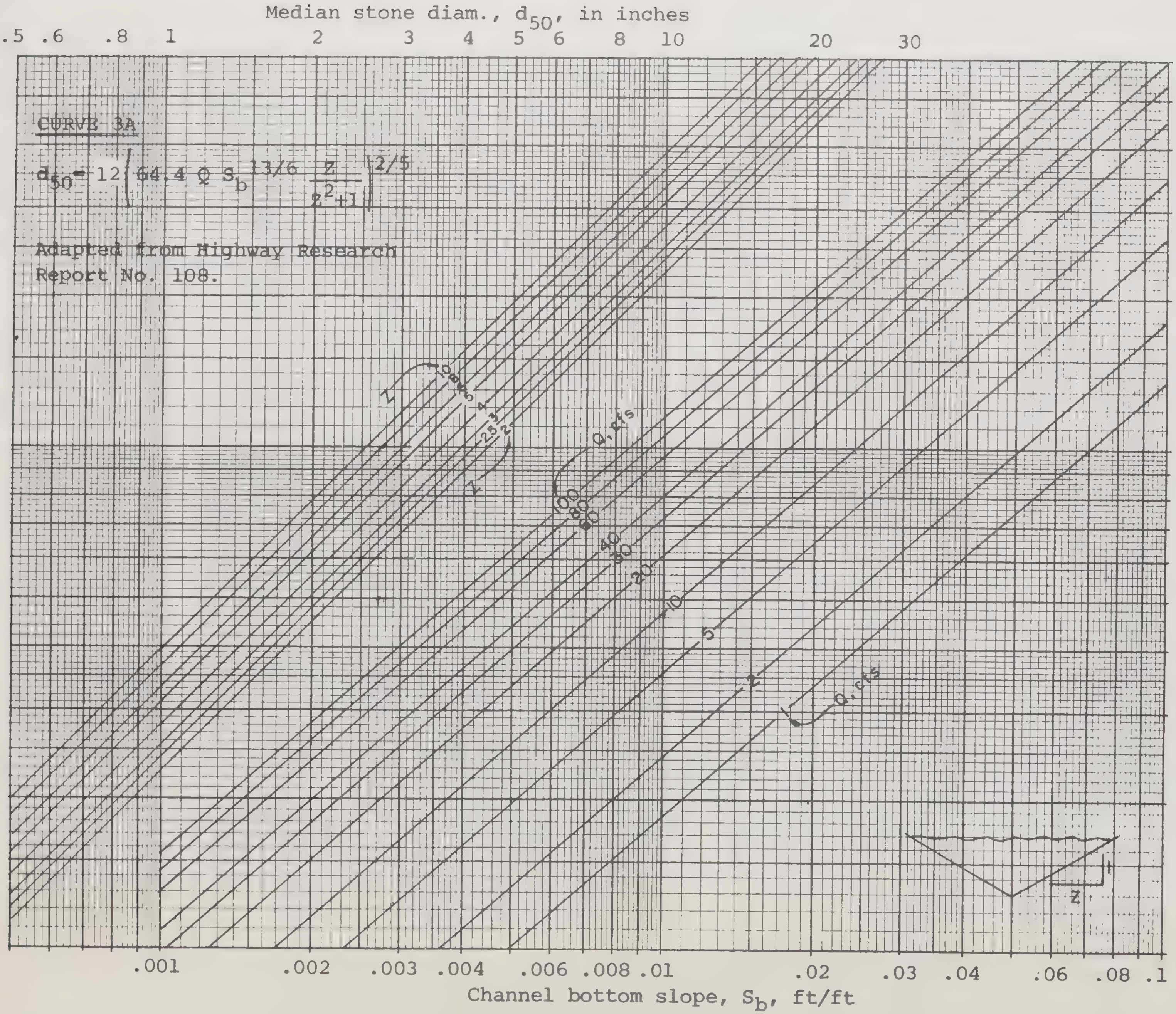


CURVE 2
Relationship of P/R to b/d in Trapezoidal Channels

MEDIAN RIPRAP DIAMETER FOR STRAIGHT TRAPEZOIDAL CHANNELS



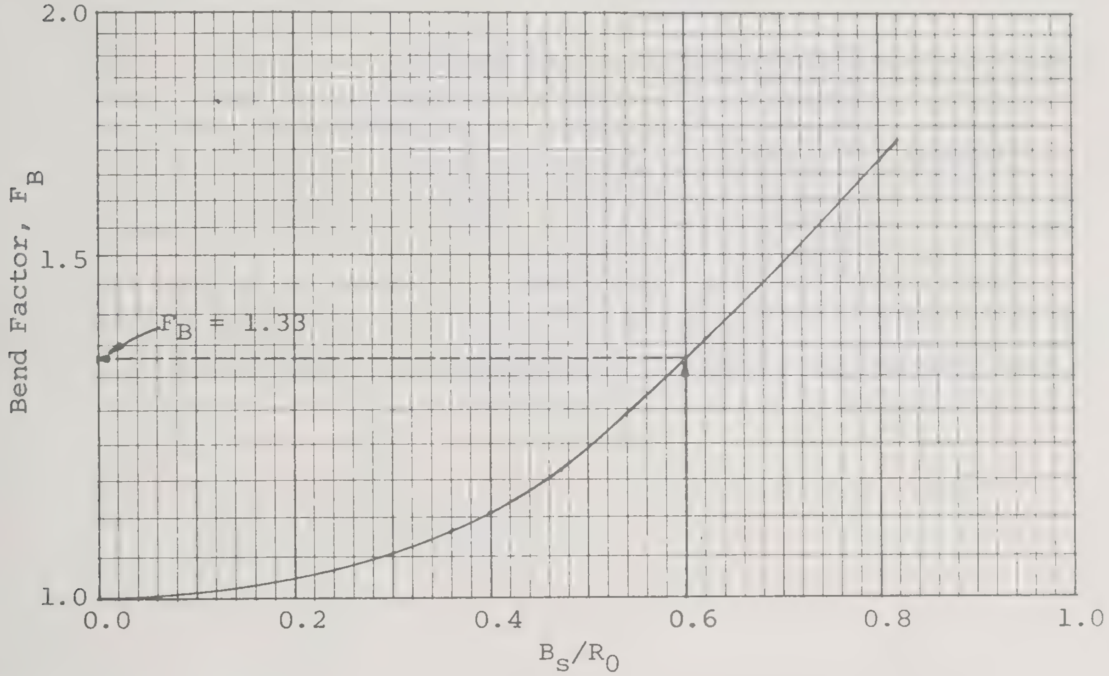
MEDIAN RIPRAP DIAMETER FOR STRAIGHT TRIANGULAR CHANNELS



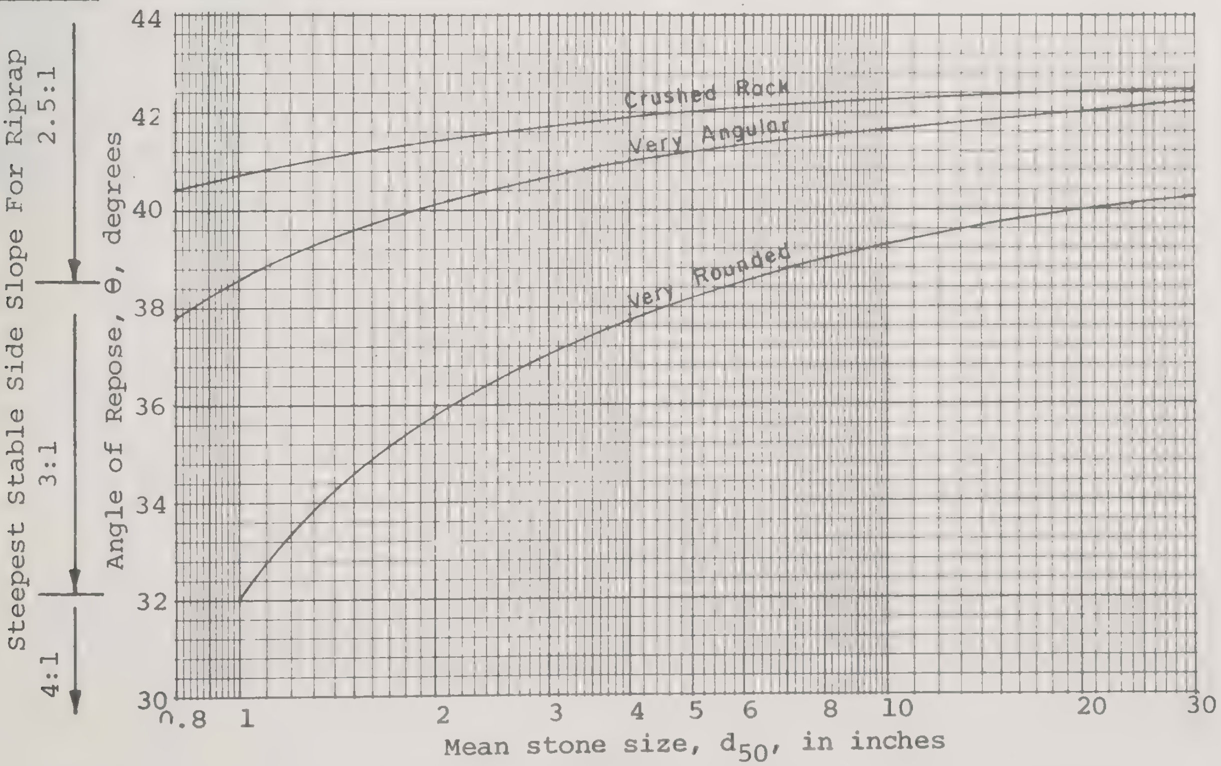
CURVE 4 - RIPRAP SIZE CORRECTION FACTOR FOR FLOW IN CHANNEL BENDS

d_{50}(for bend) = d_{50}(for straight) X F_B
B_s = channel surface width
R_o = mean radius of bend

Adapted from Highway Research Report No. 108.



CURVE 5 - MAXIMUM RIPRAP SIDE SLOPE WITH RESPECT TO RIPRAP SIZE



APPENDIX E*

Sample Design of Outlet Protection

Outlet protection as presented here is a level apron of sufficient length and flare such that the expanding flow (from pipe or conduit to channel) loses sufficient velocity and energy that it will not erode the next downstream channel reach. The design curves are based on circular conduits flowing full. The curves provide the apron size and if riprap is to be used, the minimum d_{50} size for the riprap. There are two curves, one for a low or minimum tailwater condition and the other a high or maximum tailwater condition. The minimum condition applies to a tailwater surface elevation less than the center of the pipe whereas the maximum condition applies to a tailwater surface elevation equal to or higher than the center of the pipe.

The first requirement in using this procedure is to determine the tailwater condition as required in the Standard and Specifications. Then, for circular conduits, enter the appropriate chart with the discharge and the pipe diameter to find the riprap size and apron length. Then calculate apron width.

Example 1:

A circular conduit is flowing full
Q = 280 cfs, diam. = 66", and tailwater (surface) is 2 ft. above pipe invert.

This is a minimum tailwater condition.
Read d_{50} = 1.2', and apron length = 38'
Apron width = diam + L_a = 38 + 5.5 = 43.5'
Maximum stone size in the riprap mixture = 1.5 x d_{50} = 1.5 x 1.2 = 1.8'.

The curves may also be used for the design of outlet protection for rectangular conduits but the procedure is slightly different. Depth of flow and velocity are the two flow parameters to be used. Enter the lower set of curves with velocity and depth (using the diameter curves for depth), then read to the right to find d_{50} and up and left for the length of apron. To find the apron width substitute conduit width for diameter in the apron width equations.

Example 2:

A concrete box 5.5' x 10' is flowing 5.0' deep, Q = 600 cfs and tailwater surface 5' above invert (Max. tailwater condition).

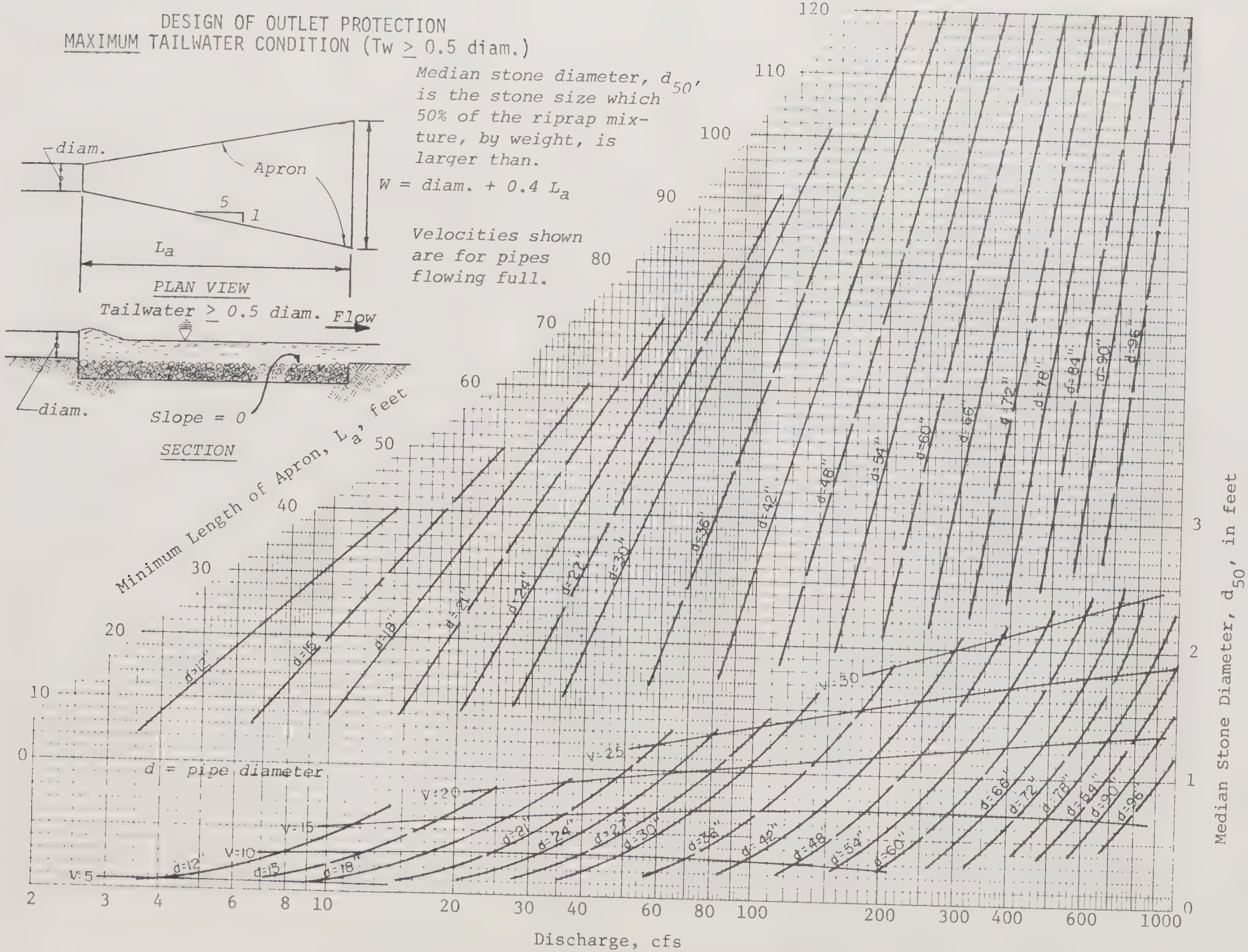
$$V = \frac{Q}{A} = \frac{600}{5.0x10} = 12 \text{ fps}$$

At the intersection of the curve d=60" and V=12 fps, read d_{50} = 0.4'.

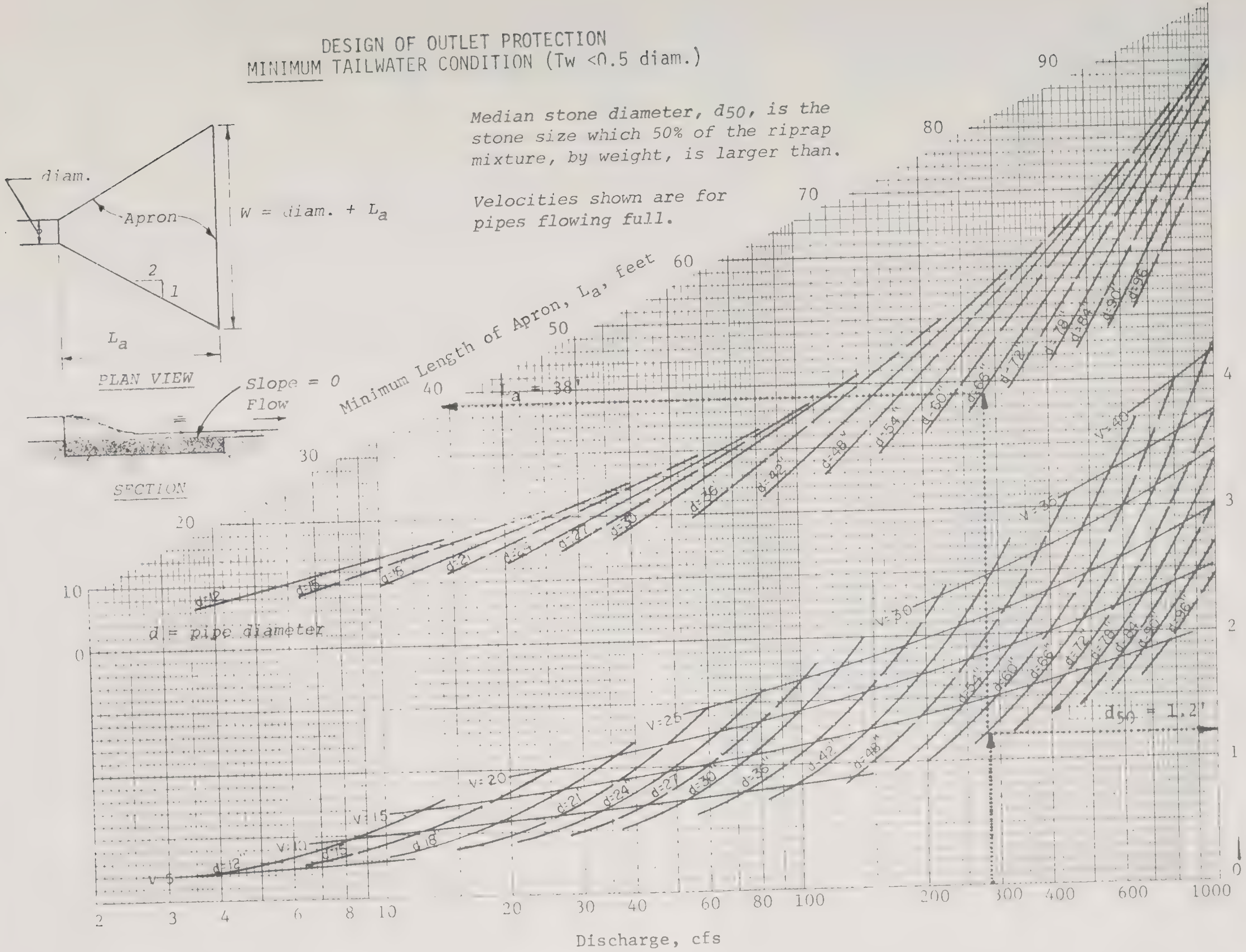
Then reading up to the d = 60" curve, read apron length = 40'.
Apron width, W = conduit width + 0.04 L_a = 10+(0.4)(40) = 26',
Largest stone size = 0.4 x 1.5 = 0.6' or 7"

*from USDA, Soil Conservation Service, College Park, Maryland. Standards and Specifications for Soil Erosion and Sediment Control in Developing Areas. July 1975.

DESIGN OF OUTLET PROTECTION
MAXIMUM TAILWATER CONDITION (Tw ≥ 0.5 diam.)



DESIGN OF OUTLET PROTECTION
MINIMUM TAILWATER CONDITION (Tw <0.5 diam.)



APPENDIX F*

Sample Determinations of Subsurface Drain Sizes

Subsurface drains ordinarily are not designed to flow under pressure and the hydraulic gradient is considered to be parallel with the grade line. The flow in the subsurface drain is considered to be open-channel flow. The size of subsurface drain required for a given capacity is dependent on the hydraulic gradient and the roughness coefficient -- "n" value -- of the subsurface drain.

The "n" values for the different materials is as follows:

Description of Pipe or Tubing	"n" value
Plastic, smooth	0.011
Asbestos Cement	0.013
Bituminized Fiber	0.013
Concrete	0.015
Corrugated Plastic	0.015
Corrugated Metal	0.025

The Standard and Specifications for Subsurface Drain states that for a systematic pattern of drains, a drainage coefficient of 1 inch to be removed in 24 hours shall be used. This coefficient is equal to 0.042 cfs. per acre of area to be drained.

Where subsurface drainage is to be by a random system, a minimum inflow rate of 1.5 cfs. per 1,000 feet of line shall be used to determine the required capacity.

If surface water is allowed to enter the system, additional capacity must be provided for and the minimum design velocity shall be 2 feet per second.

The charts are set up for different "n" values. The abscissa of the chart is the hydraulic gradient in feet per foot and the ordinate is the capacity in cubic feet per second. On the chart are plotted the full flow capacity for different pipe diameters and a velocity line for 2 feet per second. The charts are used by going to the next higher pipe diameter line from the point of intersection of the hydraulic gradient and the capacity for the required pipe size since the design is for open-channel flow. Any point to the right or below the 2 feet per second line will have a velocity of less than 2 feet per second.

Examples using the charts are as follows:

* from USDA, Soil Conservation Service, College Park, Maryland. Standards and Specifications for Soil Erosion and Sediment Control in Developing Areas. July 1975.

Example 1

A random subsurface drain is to be installed. This drain will be 700 feet in length and will be installed at a grade of 0.20%. Bituminized fiber pipe will be used. Determine the size and capacity of the drain.

Solution

From the standard, capacity required = 1.5 cfs per 1000 feet of length.

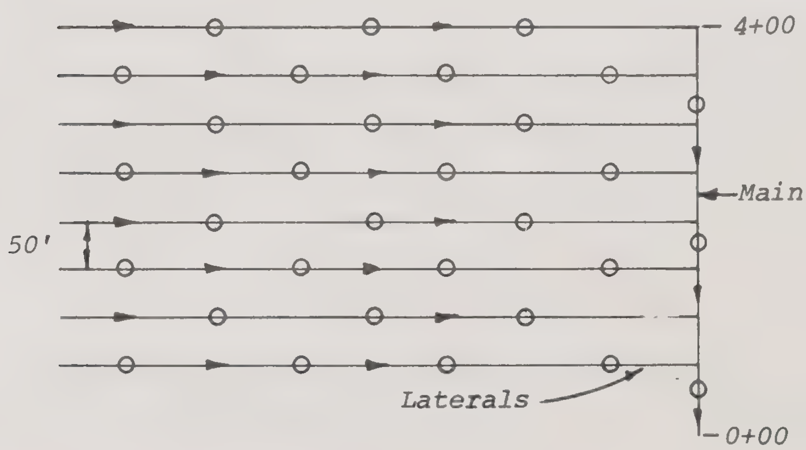
$$\text{Capacity} = \frac{700'}{1000'} \times 1.5 \text{ cfs per } 1000' = 1.05 \text{ cfs}$$

Using Subsurface Drain Capacity Chart for n = 0.013, capacity required = 1.05 cfs, and a gradient of 0.002 ft./ft., the size required is 12" and the actual capacity will be 1.58 cfs.

Example 2

A systematic pattern of subsurface drains is to be installed. There will be eight (8) laterals installed that will be spaced at fifty (50) feet center-to-center and each lateral will be 600 feet in length. The grade of the laterals will be 0.10%. The main will pick up these laterals and will be 400 feet in length. The grade of the main will be 0.10%. Determine the size and capacity of the laterals and the main at the outlet if corrugated plastic tubing is used.

PLAN VIEW



Solution

a. Size and capacity of laterals.

Each lateral will drain for a distance of 25 feet on each side of the line since the spacing is at 50 feet center-to-center. Therefore, each lateral will drain

$$\frac{600' \text{ (length)} \times 50' \text{ (width)}}{43,560} = 0.69 \text{ acre}$$

Capacity required = 0.69 acre x 0.042 cfs per acre = 0.029 cfs. Using Subsurface Drain Capacity Chart for n = 0.015, capacity required = 0.029 cfs, and a gradient of 0.001 ft./ft., the size required is 4" and the actual capacity will be 0.052 cfs. (Note: Minimum size allowed is 4".)

b. Size and capacity of the main at the outlet.

For the first 25 feet of the main from the outlet, the main will drain for a distance of 25 feet on each side. For the remaining 375 feet, the main will drain only 25 feet on the one side since the other side is included in the drainage area for the laterals. The main will also drain the laterals. Therefore:

Drainage area from laterals:

= 8 x 0.69 acre = 5.52 acres

Drainage area from main:

$$= \frac{25' \text{ (length)} \times 50' \text{ (width)}}{43,560} + \frac{375' \text{ (length)} \times 25' \text{ (width)}}{43,560} = 0.24 \text{ acre}$$

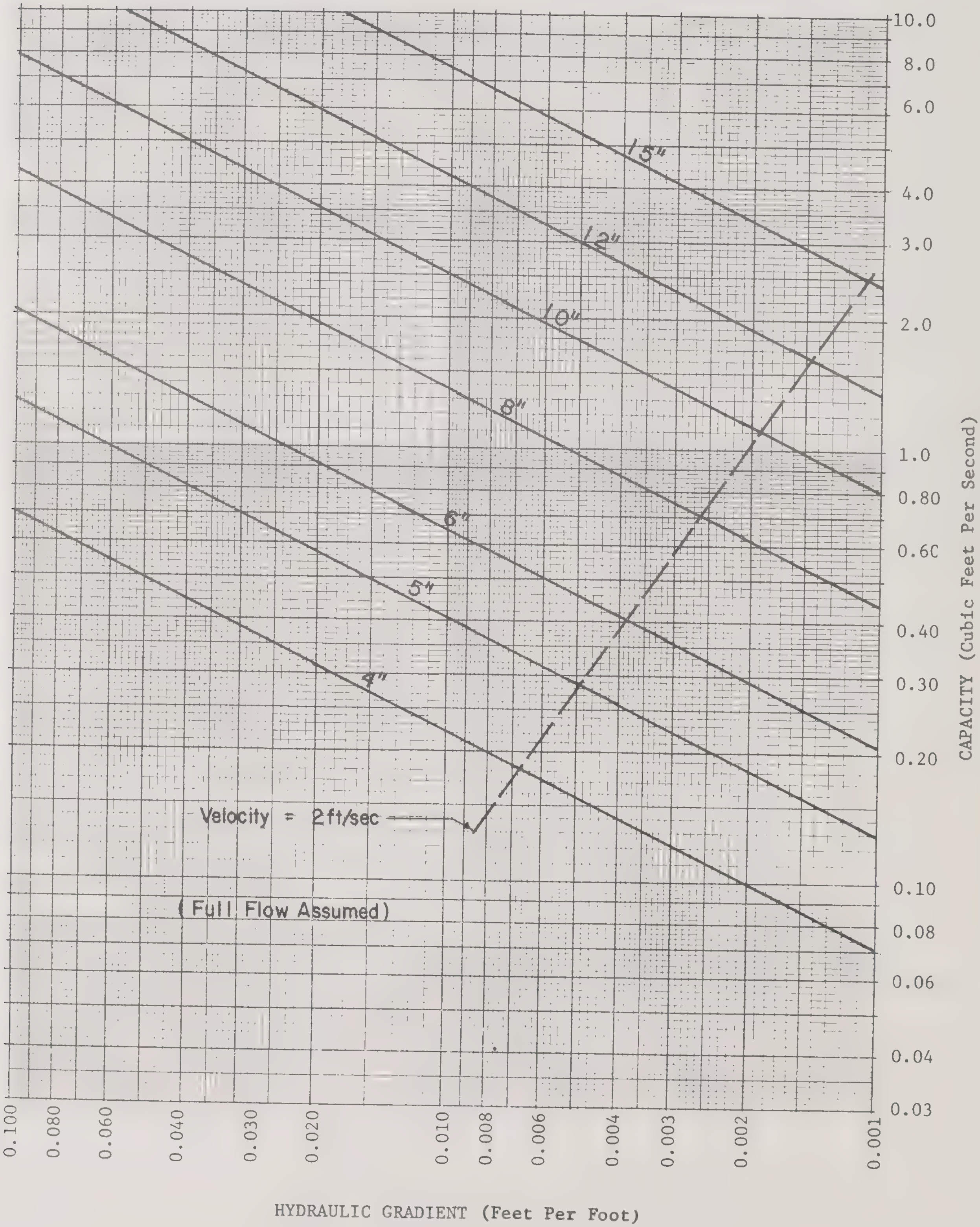
Total = 5.76 acres

Capacity required:

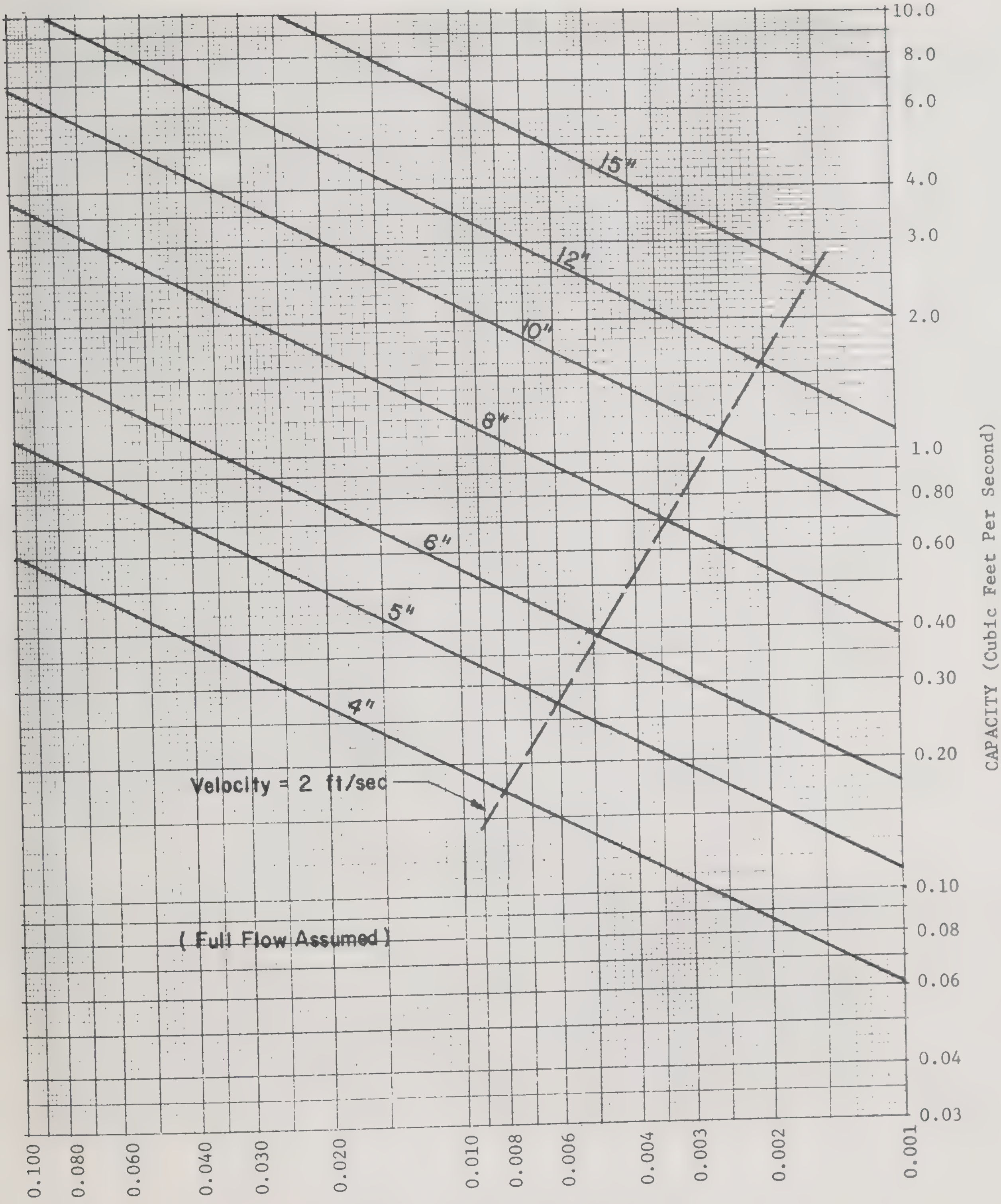
= 5.76 acres x 0.042 cfs/acre = 0.24 cfs.

Using Subsurface Drain Capacity Chart for n = 0.015, capacity required = 0.24 cfs, and a gradient of 0.001 ft./ft., the size required at the outlet is 8" and the actual capacity will be 0.33 cfs.

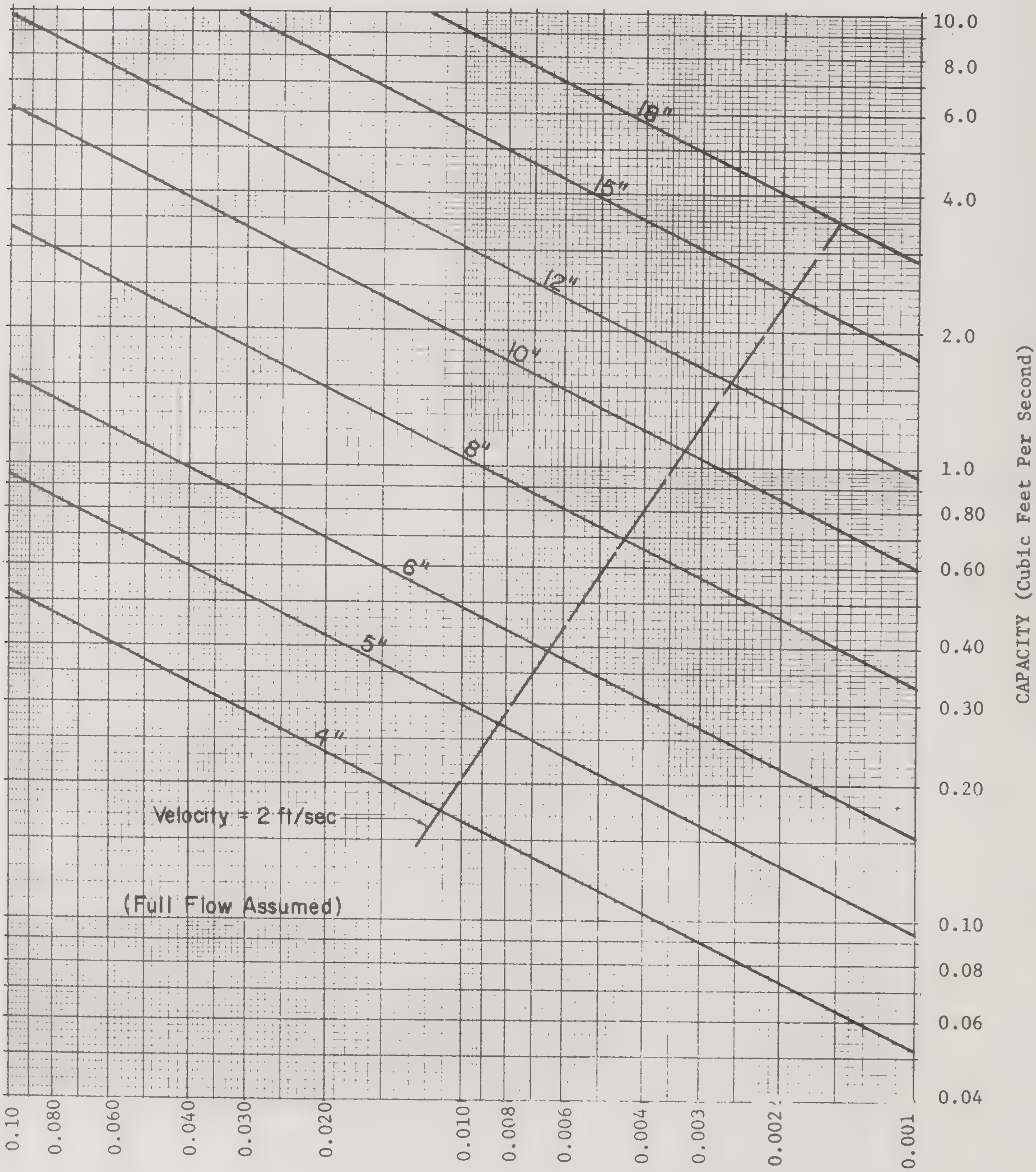
SUBSURFACE DRAIN CAPACITY CHART - n = 0.011 (14)



SUBSURFACE DRAIN CAPACITY CHART - n = 0.013

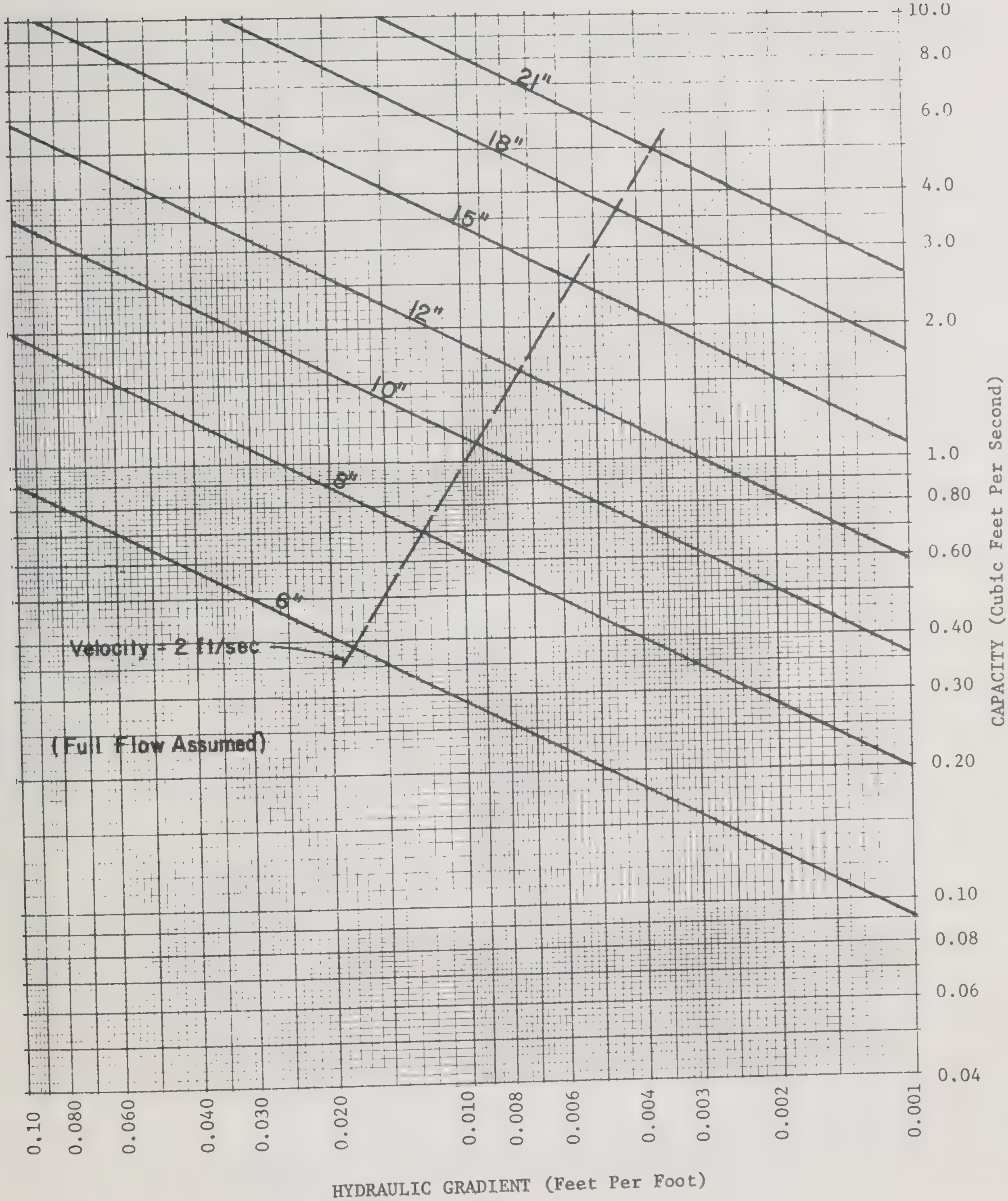


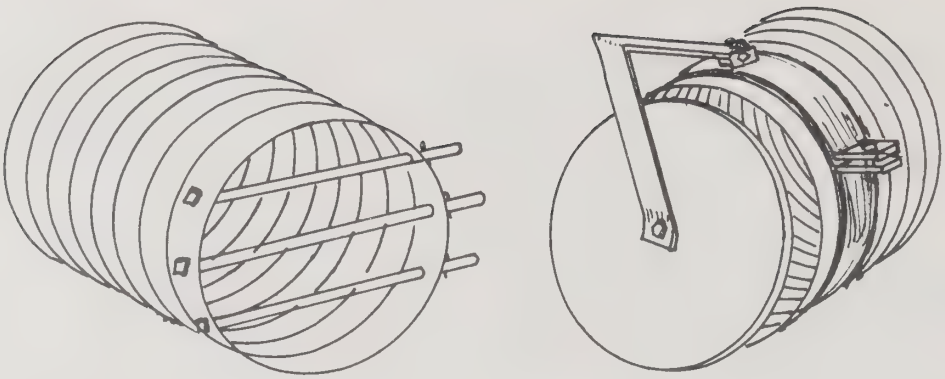
SUBSURFACE DRAIN CAPACITY CHART - n = 0.015



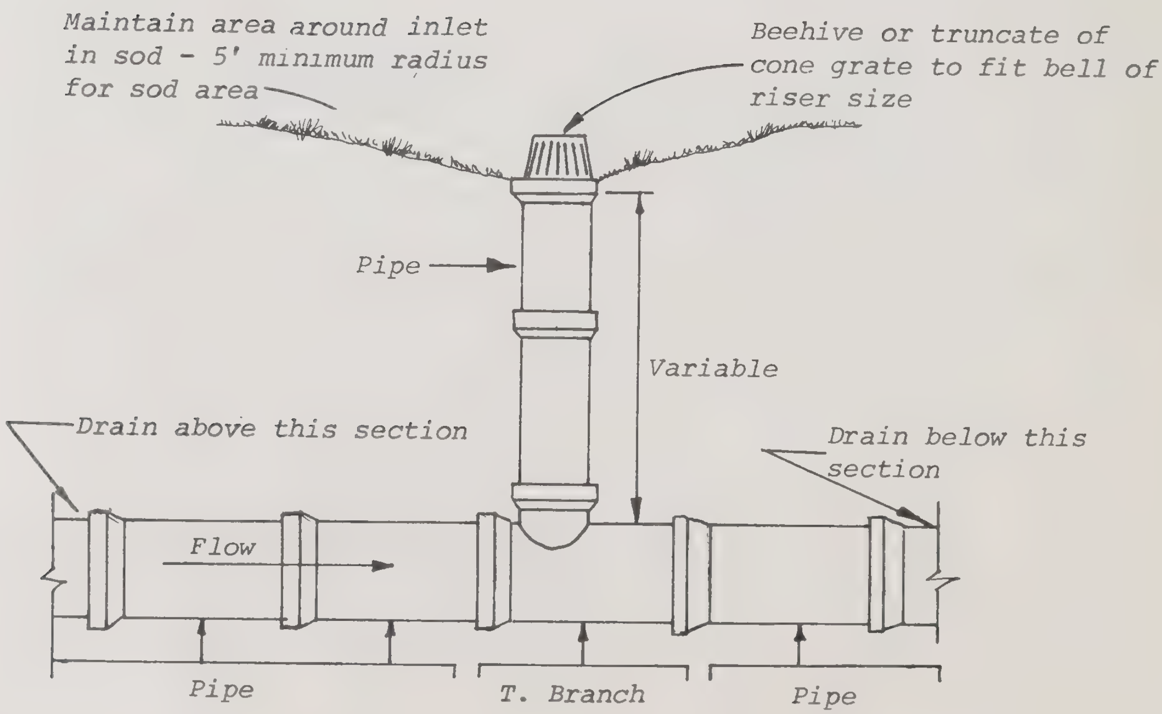
HYDRAULIC GRADIENT (Feet Per Foot)

SUBSURFACE DRAIN CAPACITY CHART - n = 0.025





RODENT PROTECTION FOR OUTLET PIPE



SURFACE WATER INLET TO SUBSURFACE DRAIN

APPENDIX G

DESIGN METHOD FOR THE SELECTION OF A STREET SWEEPING SCHEDULE

The computer program listing at the end of this appendix constitutes the Street Solids Washoff Model. The key for program inputs is shown on Table G-1. The listing shows a run using San Jose data. Lines 62 through 92 of the listing provide the four years rainfall record. Lines 353 through 377 are the model inputs which are discussed in the Design Considerations section of the standard. The illustrated San Jose run examines existing street-cleaning efficiency (line 369) as well as hypothetical efficiencies of 30% and 20% (lines 370-371). The program output consists of one page of result for each land use of each location for each of the cleaning frequencies: never, daily, once every other day, once every fourth day, weekly, once every 11th, 16th, 22nd, 29th and 37th day. Each page of output gives for the September through March season and for the April through August season the unit cost associated with the location, land use and cleaning frequency in dollars per pound of solids prevented from washing off. To allow computation of results for sweep frequencies other than those listed above, the last page of output for each location gives solids prevented from washing off as a function of cleaning frequency.

The most cost-effective street-cleaning schedule for a location is constructed by starting with the season and land use having the lowest unit cost of preventing solids from washing off, and successively adding to the program less cost-effective seasons and land uses until the available budget is exhausted. Russell (1980) gives a more detailed explanation of the use of the Street Solids Washoff Model.

Figures G-1 and G-2 illustrate the results obtained from application of the model. The San Jose example is an instance where rainy season street cleaning is much more cost effective than cleaning in the dry season. Cleaning effectiveness is approximately the same for the three land uses.

Table G-2 provides a sample direct comparison of sweeping schedules, generated by the model, which can be used to select a program tailored to fit water quality needs and budgetary constraints.

Figure G-3 gives the flow diagram for the Street Washoff Model.

Reference

Russell, Peter. Regional Evaluation of Street Sweeping as a Water Quality Control Measure. Water Quality Technical Memorandum No. 38. Association of Bay Area Governments. 1980.

TABLE G-1

PROGRAM INPUTS FOR STREET SOLIDS WASHOFF MODEL

L: Number of design areas (maximum of 4).

LU: Number of land uses (maximum of 3, same in all design areas, i.e., residential, commercial, industrial).

LOC: Name of each design area.

USE: Name of each land use.

SL: Average street solids load before cleaning for each location and land use.

SLS and SLM: For each location and land use, these are the coefficients in the equation that describes the daily solids accumulation rate as a function of the solids load on the stree at the beginning of the day. The equation is:

Street solids load at end of day = (street solids load at beginning of day x SLS) + SLM.

SE: Street cleaning efficiency for each location and land use. SE is computed as:

$$SE = 1 - \left(\frac{\text{street solids load after cleaning}}{\text{street solids load before cleaning}}\right)$$

SC: Street cleaning cost for each location in dollars per curb mile per pass.

CM: Number of curb miles for each location land use.

RT: Threshold rainfall in inches per day below which intensity no solids washoff is assumed to occur. This value is typically 0.2 inches/day except in special circumstances (Pitt, 1979).

R: Daily rainfall record in inches per day for four years considered typical for the area being modeled. Fewer years of record may be used with minor adjustments to the computer program.

RA: Rainfall adjustment factor for each location. This factor adjusts the rainfall record to account for minor differences between precipitation at the rain gauge providing the record and at the area being scheduled. RA is computed as:

$$RA = \frac{\text{rainfall at area being scheduled}}{\text{rainfall at rain gauge providing record}}$$

Unit cost of preventing solids from washing off versus sweep frequency

City of San Jose

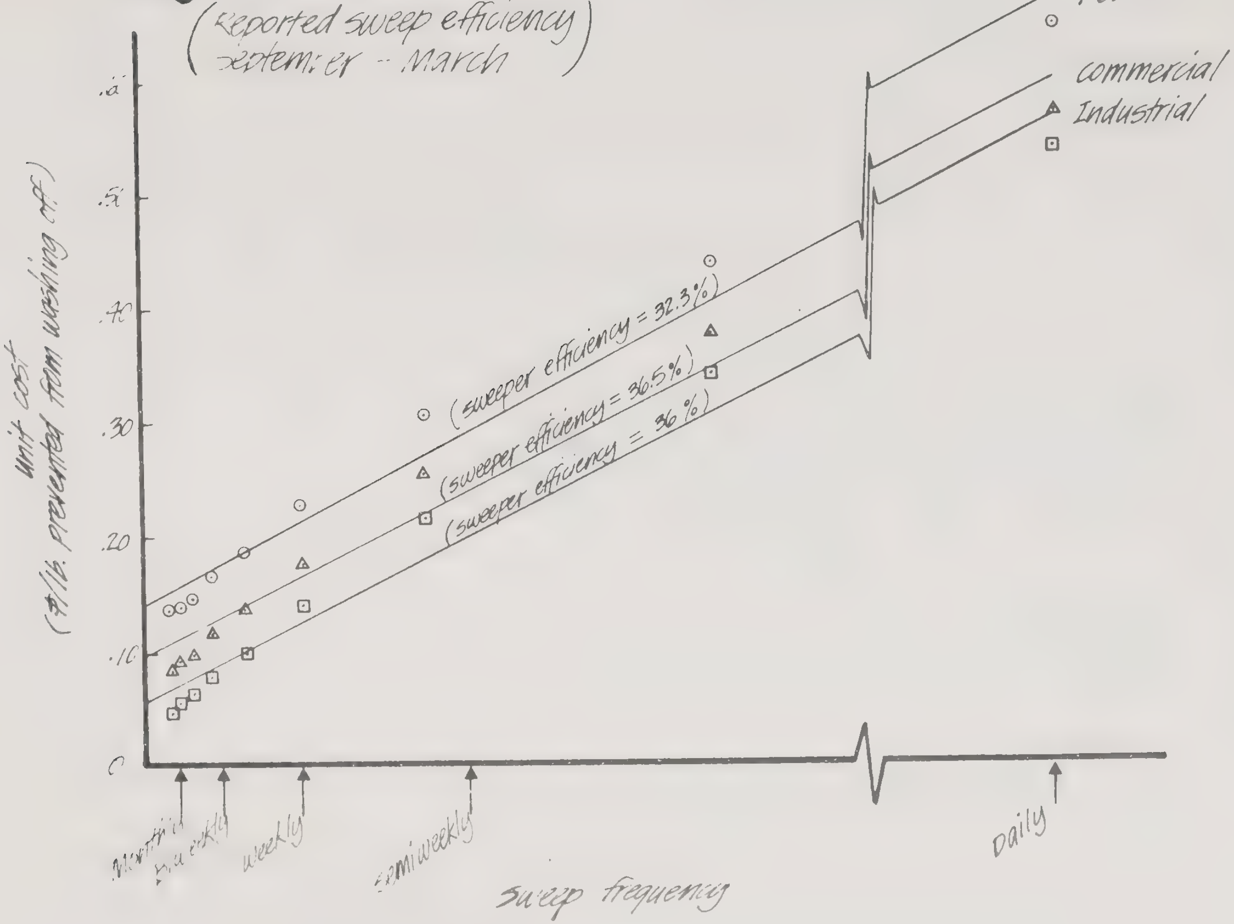


FIGURE G-1

Unit cost of preventing solids from washing off versus sweep frequency

City of San Jose (Reported sweep efficiency, April - August)

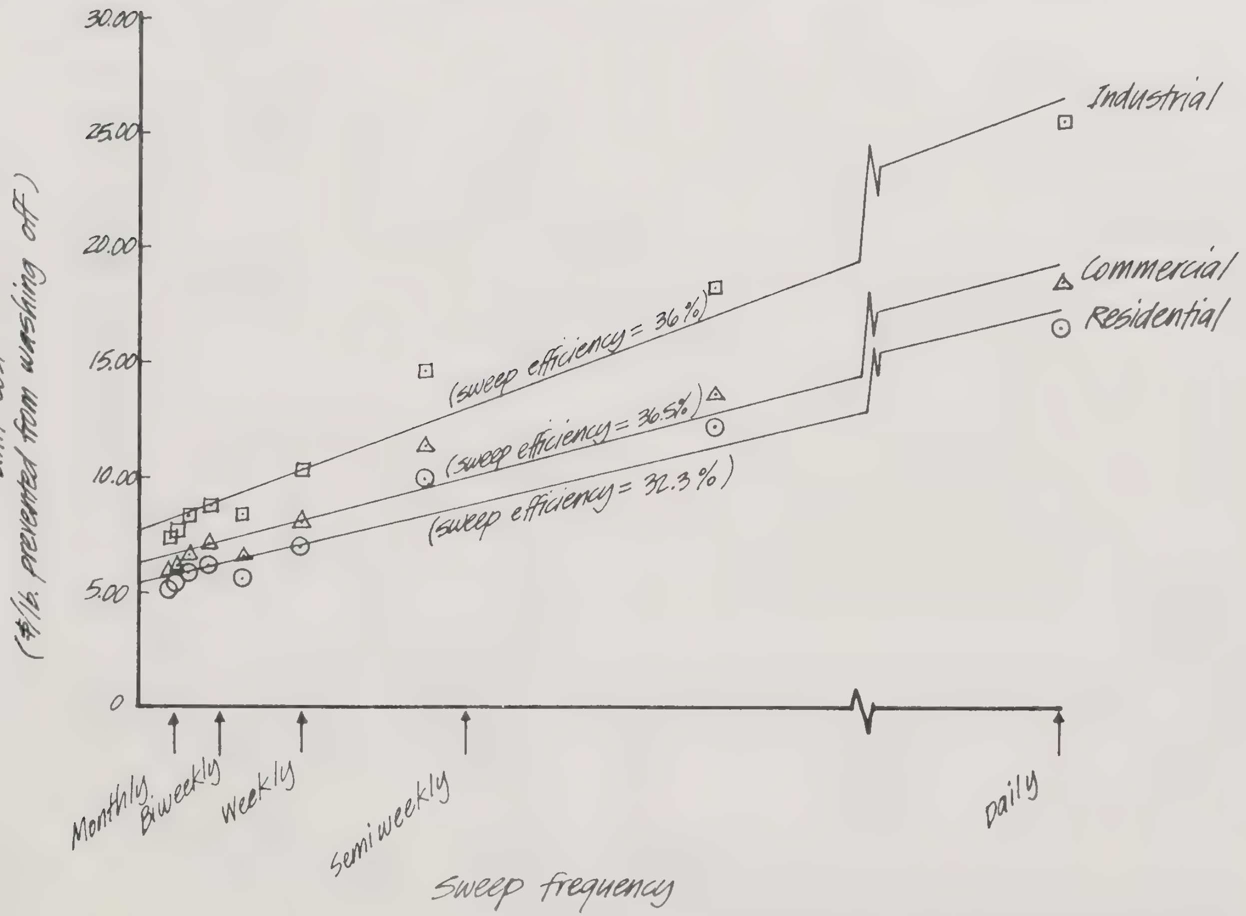


FIGURE G-2

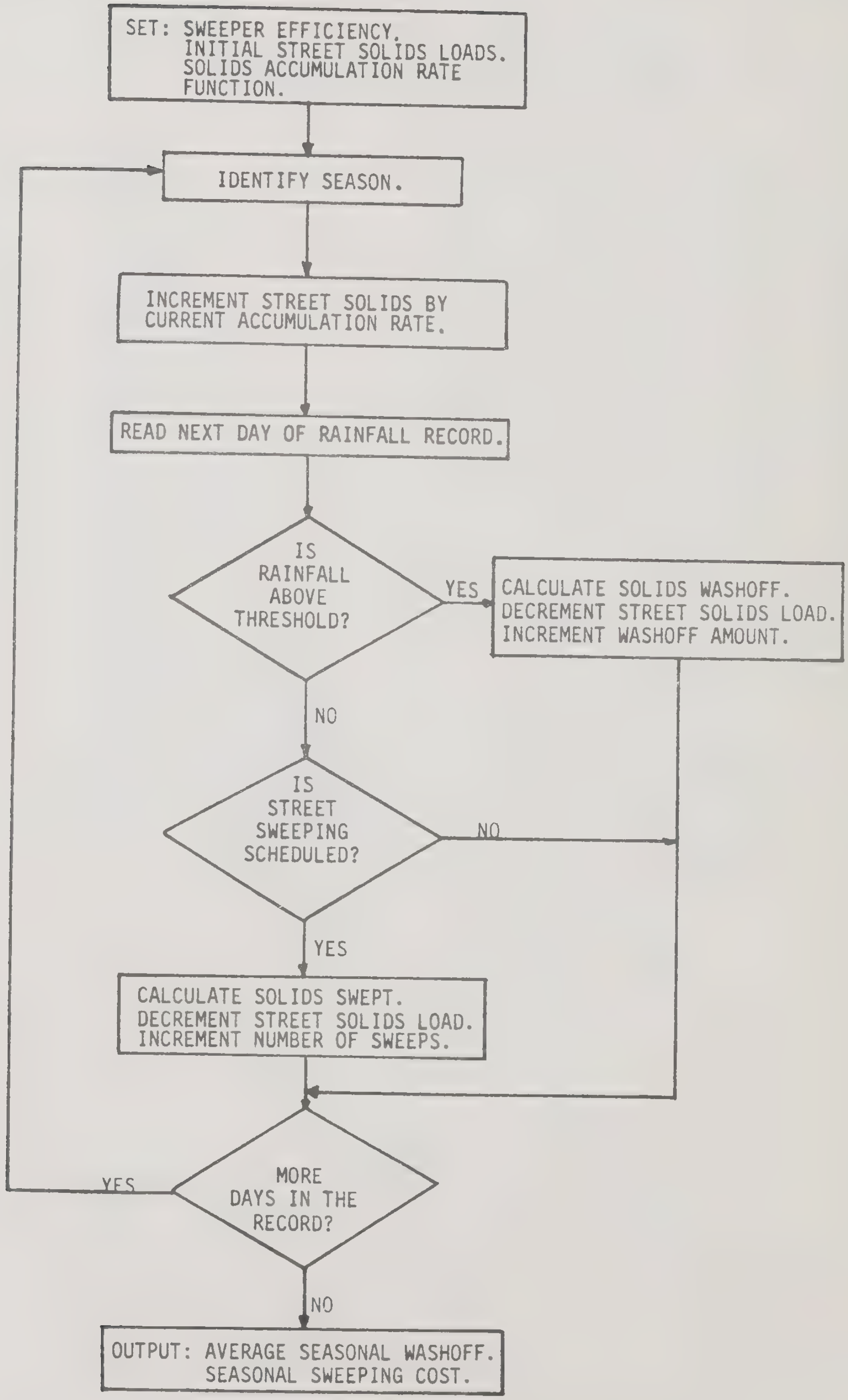
TABLE G-2

CITY OF SAN JOSE
(REPORTED SWEEPER EFFICIENCIES)

Alternative	Season						Total Washoff Prevented (1000s lb/yr)	Total Cost (1000s $/year)	Unit Cost ($/lb)
	Sept. - Mar.			Apr. - Aug.					
	Res.	Com.	Ind.	Res.	Com.	Ind.			
1			M				168	12	.07
2			B				276	25	.09
3		M	B				544	54	.10
4		B	B				759	87	.11
5		B	W				834	111	.13
6	M	B	W				1860	271	.15
7	B	B	W				2750	448	.16
8	B	W	W				2950	509	.17
9	W	W	W				3990	842	.21
10	W	W	D				4090	1040	.25
11	W	D	D				4490	1530	.34
12	D	D	D				6750	4210	.62
13	D	D	D	M			6770	4340	.64
14	D	D	D	B			6800	4480	.66
15	D	D	D	B	M		6800	4510	.66
16	D	D	D	W	M		6830	4770	.67
17	D	D	D	W	B		6830	4800	.70
18	D	D	D	W	W		6840	4850	.71
19	D	D	D	W	W	M	6840	4860	.71
20	D	D	D	W	W	B	6840	4870	.71
21	D	D	D	W	W	W	6840	4890	.71
22	D	D	D	D	W	W	6930	7050	1.02
23	D	D	D	D	D	W	6940	7440	1.07
24	D	D	D	D	D	D	6950	7600	1.09

M = Monthly
B = Biweekly
W = Weekly
D = Daily

FIGURE G-3



SOLIDS WASHOFF FLOW DIAGRAM

PROGRAM LISTING FOR STREET SOLIDS WASHOFF MODEL

```
// JOB ,DLVR),'ABAG.RUSSELL.202.40',CLASS=Y
// EXEC FORTGCLG,REGION=150K
//FORT.SYSIN DD *
C      TITLE.STREEP
C
C  GIVEN RAIN SCHEDULE, SWEEPING EFFICIENCY, AND SOLIDS ACCUMULATION
C  RATES, THIS PROGRAM CALCULATES:  SOLIDS SWEPT, SOLIDS WASHED OFF,
C  NUMBER OF PASSES FOR EACH SEASON, AND THE UNIT COSTS.
C
C  REQUIRED INPUTS:
C        LINE 1, SPACES 1 & 2
C     LM:  NUMBER OF LOCATIONS (UP TO 4)
C     LUM:  NUMBER OF LAND USES PER LOCATION (UP TO 3)
C
C        NEXT L LINES, LEFT JUSTIFY ON EACH LINE
C     LOC(L):  NAME OF EACH LOCATION
C
C        NEXT LU LINES, LEFT JUSTIFY ON EACH LINE
C     USE(LU):  NAME OF EACH LAND USE
C
      INTEGER KS, LUM, LM
C
C        NEXT L LINES, LU F6.1 ENTRIES ABUTTING EACH OTHER
C     SL(L,LU):  AVERAGE STREET SOLIDS LOAD FOR EACH LOCATION
C          AND LAND USE.
C
C        NEXT L LINES, LU F8.4 ENTRIES ABUTTING EACH OTHER
C     SLS(L,LU):  SLOPE OF THE SOLIDS LOADING RATE CURVE  -
C          DAY'S LOAD INC. = LOAD X SLOPE + MAX. LOADING RATE
C
C        NEXT L LINES, LU F7.2 ENTRIES ABUTTING EACH OTHER
C     SLM(L,LU):  MAXIMUM STREET SOLIDS LOADING RATE IN LBS PER
C          CURB MILE PER DAY FOR EACH LOCATION AND LAND USE.
C
C        NEXT L LINES, LU F5.3 ENTRIES ABUTTING EACH OTHER
C     SE(L,LU):  STREET SWEEPING EFFICIENCY FOR EACH LOCATION
C          AND LAND USE.
C
C        NEXT LINE, L F6.2 ENTRIES ABUTTING EACH OTHER
C     SC(L):  SWEEPING COSTS FOR EACH LOCATION IN DOLLARS PER
C          CURB MILE PER PASS.
C
      REAL R(1460), RA(4), RT, SE(4,3), SR(2), CR(2), SL(4,3),
     +RR12(730), RR34(730), SLS(4,3)
C
C        NEXT L LINES, LU F6.1 ENTRIES ABUTTING EACH OTHER
C     CM(L,LU):  CURB-MILES FOR EACH LOCATION AND LAND USE.
C
C        NEXT LINE, LEFT JUSTIFY F4.3
C     RT:  THRESHOLD RAINFALL IN INCHES PER DAY.
C
C        NEXT LINE, L F5.3 ENTRIES ABUTTING EACH OTHER
C     RA(L):  RAINFALL ADJUSTMENT FACTOR.
```

```
C
C  VARIABLES AND ARRAYS:
      REAL WD(2,10,3), LOC(4,5), USE (3,3), NR(2,10), NR(2),
     +UC(2), AR(2), SC(4), SEA(2,5), SEC(2), USR(2),
     +SLM(4,3), D, WDF(2), UWF(2,10,3), CM(4,3), WFT(2), SCT(2)
      REAL NRS(2), SRR, SRRS, R1(2,3), R2(2,3), R4(2,3), R6(2,3),
     +SRY1, SS2, SRY2, SR12, SS1, B1, B2, A, RSLD(2,3), RINT(2,3),
     +RSEE(2,3)
C
C  FIRST TWO YEARS OF RAINFALL RECORD:  10/1/69 THROUGH 9/30/71.
C
      DATA RR12/9*.0,.03,3*.0,.03,.36,.19,.01,18*.0,.79,.13,.01,
     +26*.0,.01,3*.0,.27,.0,.08,.01,6*.0,.06,.28,.03,.51,2*.0,.01,
     +.31,14*.0,.66,.04,.65,.02,.04,.95,.26,.2,.08,.0,.1,.31,.19,.0,
     +.19,.05,2*.0,.28,12*.0,.14,.01,.02,.13,.34,2*.0,.23,.05,9*.0,
     +.27,.31,1.05,2*.0,1.01,3*.0,.07,.04,.01,33*.0,.13,5*.0,.05,
     +6*.0,.03,13*.0,.02,27*.0,.1,134*.0,.05,.06,.0,.24,10*.0,.3,.36,
     +.14,.53,5*.0,.02,11*.0,.24,.6,.07,.04,2.72,1.13,.07,.46,.38,.0,
     +.1,3*.0,.01,6*.0,.23,.3,.22,.73,.06,.79,.25,3*.0,.02,.19,.11,
     +.0,.04,2*.0,.1,.01,8*.0,.09,.46,.13,.1,4*.0,.01,.01,26*.0,.24,
     +.0,.13,.03,7*.0,.14,12*.0,.58,.02,.25,8*.0,.14,.0,.25,.32,5*.0,
     +8*.0,.12,.03,2*.0,.38,2*.0,.16,.34,.0,.02,12*.0,.03,10*.0,.01,
     +13*.0,.02,.01,.01,86*.0,.01,36*.0,.12/
C
C  SECOND TWO YEARS OF RAINFALL RECOND: 10/1/71 THROUGH 9/30/73.
C
      DATA RR34/41*.0,.06,.12,.26,
     +13*.0,.01,.17,.08,2*.0,.68,.09,2*.0,.02,2*.0,.02,.11,.0,.03,.0,
     +.01,7*.0,.56,.28,.11,.69,.0,.6,.0,.09,20*.0,.01,3*.0,.08,.0,
     +.22,.03,.86,.01,5*.0,.02,.05,.22,16*.0,.03,5*.0,.01,21*.0,.07,
     +13*.0,.09,.05,4*.0,.09,.0,.11,10*.0,.17,45*.0,.14,108*.0,.01,
     +.59,4*.0,.01,.0,.02,4*.0,.33,.34,.08,.15,.04,.44,.26,.4,.1,.02,
     +15*.0,.02,.72,2*.0,.17,2*.0,.58,1.23,.0,.65,1.23,.39,.44,.0,
     +.02,.03,13*.0,.03,.09,.0,.31,.26,.01,7*.0,.04,.24,.03,.07,2*.0,
     +.02,.0,.03,3*.0,.05,10*.0,.4,.97,.07,.16,4*.0,1.38,.22,.8,.02,
     +.0,.12,3*.0,.3,3*.0,.07,.57,.04,2*.0,.31,.69,.0,1.08,.15,.0,
     +.04,.37,.78,.16,.5,.25,9*.0,.21,.0,.53,.65,.25,2*.0,.44,.13,.0,
     +.34,.0,.27,2*.0,.21,7*.0,.25,.66,.35,4*.0,.02,3*.0,.06,
     +.02,12*.0,.04,.01,39*.0,.01,121*.0,.01,.03,6*.0/
      DO 5 I=1,730
      R(I)=RR12(I)
      R(I+730)=RR34(I)
    5 CONTINUE
      DATA SEA/'SEPT','APRI','EMBE','L TH',
     +'R TH','RU A','RU M','UGUS','ARCH','T   '/
      IDIN=5
      IDOUT=6
C
C  READ THE JOB INPUTS.
C
      READ (IDIN,10) LM, LUM
   10 FORMAT (2I1)
      READ (IDIN,15) ((LOC(J,K), K=1,5), J=1,LM)
   15 FORMAT (5A4)
      READ (IDIN,20) ((USE(J,K),  K=1,3), J=1,LUM)
   20 FORMAT (3A4)
```

```
      READ (IDIN,25) ((SL(J,K), K=1,LUM), J=1,LM)
   25 FORMAT (3F6.1)
      READ (IDIN,27) ((SLS(J,K), K=1,LUM), J=1,LM)
   27 FORMAT (3F8.4)
      READ (IDIN,30) ((SLM(J,K), K=1,LUM), J=1,LM)
   30 FORMAT (3F7.2)
      READ (IDIN,35) ((SE(J,K), K=1,LUM), J=1,LM)
   35 FORMAT (3F5.3)
      READ (IDIN,40) (SC(J), J=1,LM)
   40 FORMAT (4F6.2)
      READ (IDIN,25) ((CM(J,K), K=1,LUM), J=1,LM)
      READ (IDIN,45) RT
   45 FORMAT (F4.3)
      READ (IDIN,46) (RA(J), J=1,LM)
   46 FORMAT (4F5.3)
C
C  EXAMINE EACH LOCATION.
C
      DO 300 L=1,3
      WRITE (IDOUT,105)
  105 FORMAT ('1ABAG - STREET SWEEPING EFFECTIVENESS MODEL',
     +/,'        BY PETER RUSSELL, MARCH 1980',//)
      WRITE (IDOUT,110) (LOC(L,K), K=1,5)
  110 FORMAT ('0', 10X, 5A4, //)
C
C  PRINT OUT THE PARAMETERS USED FOR THE LOCATION.
C
      WRITE (IDOUT,112)
  112 FORMAT ('   LAND USE    AVE. LOAD    ACCUM. SLOPE', 4X,
     +'MAX. ACCUM RATE', 7X, 'SWEEPING', 8X, 'CURB-MILES', /, 16X,
     +'LB/C-MI', 24X, 'LB/C-MI/DAY', 8X, 'EFFICIENCY',//)
      DO 400 LU=1,LUM
  400 WRITE (IDOUT,114) ((USE(LU,K), K=1,3), SL(L,LU), SLS(L,LU),
     +SLM(L,LU), SE(L,LU), CM(L,LU))
  114 FORMAT ('0',3A4,4X,F5.0,12X,F7.4,9X,F6.2,13X,F4.3,12X,F6.1)
      WRITE (IDOUT,116) SC(L)
  116 FORMAT (//, '0STREET SWEEPING COST:  $', F5.2, '/C-MI/PASS.')
      WRITE (IDOUT,118) RA(L), (LOC(L,K), K=1,5), RT
  118 FORMAT('0RAINFALL ADJUSTMENT FACTOR  = ', F4.2, ' FOR ',
     +5A4, '.', //, ' THE THRESHOLD RAINFALL FOR COMPUTING',
     +' WASHOFF IS ', F3.2, ' INCHES/DAY.')
      DO 350 I=1,2
      DO 350 J=1,LUM
      R1(I,J)=0.
      R2(I,J)=0.
      R4(I,J)=0.
      R6(I,J)=0.
  350 CONTINUE
C
C  EXAMINE SWEEP PERIODS OF 1, 2, 4, 7, 11, 16, 22, 29 AND 37 DAYS.
C
      SP=1.
      DO 200 KA=1,10
      SP=SP+KA-2
      IF (KA.EQ.1) SPR=0.
      IF (KA.EQ.1) SPRS=0.
```

```
      DO 200 LU=1,LUM
      IF (KA.EQ.1) SP=9999.
C
C  SET THE BOOKKEEPING VARIABLES EQUAL TO ZERO.
C
      DO 500 KS=1,2
      NP(KS,KA)=0.
      IF (KA.EQ.1) NPS(KS)=0.
      SR(KS)=0.
      NR(KS)=0.
      WD(KS,KA,LU)=0.
      CR(KS)=0.
  500 CONTINUE
C
C  EXAMINE EACH LAND USE IN THE LOCATION.
C
      SS=SL(L,LU)
      WRITE (IDOUT,105)
      WRITE (IDOUT,110) (LOC (L,K), K=1,5)
      WRITE (IDOUT,120) SP
  120 FORMAT (' FOR A SWEEPING FREQUENCY OF ONCE EVERY ',
     + F5.0, ' DAYS:')
      WRITE (IDOUT,125) (USE(LU,K), K=1,3)
  125 FORMAT (' ', 3A4, 'LAND USE:', /)
C
C  RUN FOUR YEAR'S RAIN DATA SEVEN TIMES, EACH BEGINNING
C        WITH A DIFFERENT DAY OF THE WEEK.
C
      D=0.
      NY=7
      DO 100 ID=1,NY
C
C  RUN FOUR YEAR'S DATA.
C
      DO 100 I=1,1460
      D=D+1
C
C  ADD DAY'S INCREMENT OF SOLIDS TO THE STREET SURFACE.
C
      SS=SS+SLS(L,LU)+SLM(L,LU)
C
C  IDENTIFY THE SEASON:  1=NOVEMBER THRU MARCH, 2=APRIL THRU AUGUST.
C
      KS=2
      IF ((I.LE.182).OR.((I.GE.336).AND.(I.LE.547)).OR.((I.GE.701)
     +.AND.(I.LE.912)).OR.((I.GE.1066).AND.(I.LE.1277)).OR.
     +(I.GE.1431)) KS=1
C
C  IS THE DAY A MULTIPLE OF THE SWEEP PERIOD?
C
      M=0
      IF (D/SP-AINT(D/SP).NE.0.) M=1
C
C  IS THE DAY A SUNDAY OR SATURDAY?
C
      IF(((D-1)/7.-AINT((D-1)/7.).EQ.0.).OR.(D/7.-
     +AINT(D/7.).EQ.0.)) M=1
```

```
      C
      C  IS THE DAY A MONDAY FOLLOWING A WEEKEND MULTIPLE OF THE SWEEP
      C       PERIOD?
      C
           IF (((D-2)/7.-AINT((D-2)/7.).EQ.0.).AND.(((D-1)/SP-
          +AINT((D-1)/SP).EQ.0.).OR.((D-2)/SP-AINT((D-2)/
          +SP).EQ.0.))) M=0
      C
      C  IS THE DAY'S RAIN ABOVE THE THRESHOLD?
      C
           IF (R(I)*RA(L).GE.RT) GO TO 50
      C
      C  IS SWEEPING TO BE DONE?
      C
           IF (M.EQ.1) GO TO 100
           IF (SP.EQ.9999.) GO TO 100
      C
      C  SWEEP THE STREET, TALLY SOLIDS AND COUNT THE PASS.
      C
           NP(KS,KA)=NP(KS,KA)+1
           SR(KS)=SR(KS)+SS*SE(L,LU)
           SS=SS*(1-SE(L,LU))
           GO TO 100
      C
      C  RAIN EVENT:  TALLY SOLIDS, COUNT THE RAIN DAY AND TALLY RAIN.
      C
        50 NR(KS)=NR(KS)+1
           WD(KS,KA,LU)=WD(KS,KA,LU)+SS*(1-EXP(-3.91*R(I)*RA(L)))
           SS=SS*EXP(-3.91*R(I)*RA(L))
           CR(KS)=CR(KS)+(R(I)*RA(L))
       100 CONTINUE
           IF ((LU.EQ.1).AND.(KA.NE.1)) SPR=SPR+1/SP
           IF ((LU.EQ.1).AND.(KA.NE.1)) SPRS=SPRS+(1/SP)**2
           DO 200 KS=1,2
           NP(KS,KA)=NP(KS,KA)/(4*NY)
           IF (LU.EQ.1) NPS(KS)=NPS(KS)+NP(KS,KA)
           SR(KS)=SR(KS)/(4*NY)
           NR(KS)=NR(KS)/(4*NY)
           WD(KS,KA,LU)=WD(KS,KA,LU)/(4*NY)
           WDF(KS)=WD(KS,1,LU)-WD(KS,KA,LU)
           CR(KS)=CR(KS)/(4*NY)
           AR(KS)=CR(KS)/NR(KS)
           SEC(KS)=SC(L)*NP(KS,KA)
           IF (NP(KS,KA).EQ.0.) GO TO 900
           UC(KS)=SC(L)*NP(KS,KA)/SR(KS)
           USR(KS)=SR(KS)/NP(KS,KA)
           UWF(KS,KA,LU)=SC(L)*NP(KS,KA)/WDF(KS)
           GO TO 800
       900 USR(KS)=0.
           UC(KS)=0.
           UWF(KS,KA,LU)=0.
       800 CONTINUE
           WFT(KS)=WDF(KS)*CM(L,LU)
           SCT(KS)=SEC(KS)*CM(L,LU)
```

?

```
C
C  TABULATE THE RESULTS FOR EACH SEASON.
C
      WRITE (IDOUT,150) (SEA(KS,K), K=1,5)
  150 FORMAT (' ', 24X, 6A4)
      WRITE (IDOUT,152) NR(KS), CR(KS), AR(KS)
  152 FORMAT ('0', F5.1, ' SIGNIFICANT RAIN DAYS.', 12X,
     +'CUMULATIVE TOTAL  = ', F4.1, ' INCHES/SEASON.',
     +/, ' THE AVERAGE RAIN  = ', F4.2, ' INCHES/DAY.')
      WRITE (IDOUT,154) NP(KS,KA), SP(KS), USR(KS), SEC(KS), UC(KS),
     +WD(KS,KA,LU)
  154 FORMAT ('0ACTIVITY  = ', F5.1, ' PASSES/SEASON.',
     +/, '0SOLIDS SWEPT UP  = ', F7.1, ' LB/C-MI  = ', F8.2,
     +' LB/C-MI/PASS.', /, ' SWEEPING COST  =  $', F8.2,
     +'/C-MI/SEASON  =  $', F6.3, '/LB SWEPT UP.', /,
     +'0WASHOFF  = ', F7.1, ' LB/C-MI/SEASON.')
      WRITE (IDOUT,156) WOF(KS), UWF(KS,KA,LU)
  156 FORMAT ('0WASHOFF FORGONE  = ', F7.1, ' LB/C-MI/SEASON  =  $',
     +F8.3, '/LB PREVENTED FROM WASHING OFF.')
      WRITE (IDOUT,158) WFT(KS), SCT(KS)
  158 FORMAT (' TOTAL WASHOFF FORGONE  = ', F10.0, ' LB/SEASON.',
     + '       TOTAL COST  =  $', F10.0, '/SEASON.', //)
      IF (KA.EQ.1) SP=1
      IF (KA.EQ.1) GO TO 200
      R1(KS,LU)=R1(KS,LU)+1
      R2(KS,LU)=R2(KS,LU)+UWF(KS,KA,LU)/SP
      R4(KS,LU)=R4(KS,LU)+UWF(KS,KA,LU)
      R6(KS,LU)=R6(KS,LU)+(UWF(KS,KA,LU))**2
  200 CONTINUE
      WRITE(IDOUT,105)
      WRITE (IDOUT,110) (LOC(L,K), K=1,5)
      WRITE(IDOUT,162)
  162 FORMAT(' THE BEST FIT COEFFICIENTS DEFINING THE',
     +' UNIT COST OF SOLIDS KEPT FROM WASHING OFF ARE:', /,
     +15X, '$/LB  =  A X (1/SWEEP PERIOD) + B')
      DO 300 KS=1,2
      WRITE (IDOUT, 163)
  163 FORMAT (/)
      WRITE (IDOUT,150) (SEA(KS,K), K=1,5)
      DO 310 LU=1,LUM
      RSLO(KS,LU)=(R1(KS,LU)*R2(KS,LU)-SPR*R4(KS,LU))/
     +(R1(KS,LU)*SPRS-SPR**2)
      RINT(KS,LU)=(R4(KS,LU)*SPRS-SPR*R2(KS,LU))/
     +(R1(KS,LU)*SPRS-SPR**2)
      RSEE(KS,LU)=SQRT((R6(KS,LU)-RINT(KS,LU)*R4(KS,LU)-
     +RSLO(KS,LU)*R2(KS,LU))/(R1(KS,LU)-2))
      WRITE (IDOUT,164) (USE(LU,K), K=1,3), RSLO(KS,LU), RINT(KS,LU),
     +RSEE(KS,LU)
  164 FORMAT ('0', 3A4, 10X, 'A  = ', F9.5, 10X, 'B  = ', F9.5, /,
     +' STANDARD ERROR OF ESTIMATE  =  $', F7.3, '/LB.')
  310 CONTINUE
      SPY1=0.
      SS2=0.
      SPY2=0.
      SP12=0.
      SS1=0.
      SP=1.
```

```
      DO 330 KA=2,10
      SP=SP+KA-2
      SPY1=SPY1+(NP(KS,KA)-SPR/R1(KS,1))*(1/SP-SPR/R1(KS,1))
      SS2=SS2+((1/SP)**2-SPRS/R1(KS,1))**2
      SPY2=SPY2+(NP(KS,KA)-SPR/R1(KS,1))*((1/SP)**2-SPRS/R1(KS,1))
      SP12=SP12+(1/SP-SPR/R1(KS,1))*((1/SP)**2-SPRS/R1(KS,1))
      SS1=SS1+(1/SP-SPR/R1(KS,1))**2
  330 CONTINUE
      B1=(SPY1*SS2-SPY2*SP12)/(SS1*SS2-(SP12)**2)
      B2=(SPY2*SS1-SPY1*SP12)/(SS1*SS2-(SP12)**2)
      A=NPS(KS)/R1(KS,1)-B1*SPR/R1(KS,1)-B2*SPRS/R1(KS,1)
      WRITE (IDOUT,170) (SEA(KS,K), K=1,5), A, B1, B2
  170 FORMAT ('0NUMBER OF PASSES DURING ', 5A4, '= ', F7.3, ' + ',
     +F8.3, ' X (1/SWEEP PERIOD) + ', F8.3, ' X (1/SWEEP PERIOD)**2.
     +', //)
  300 CONTINUE
      STOP
      END
/*
//GO.SYSIN DD *
33
CITY OF SAN JOSE
CITY OF SAN JOSE
CITY OF SAN JOSE
RESIDENTIAL
COMMERCIAL
INDUSTRIAL
 489.1 757.6 626.7
 489.1 757.6 626.7
 489.1 757.6 626.7
    .9722   .9859   .9961
    .9722   .9859   .9961
    .9722   .9859   .9961
  30.56  24.47  15.32
  30.56  24.47  15.32
  30.56  24.47  15.32
 .365 .323 .36
 .3   .3   .3
 .2   .2   .2
 14.00 14.00 14.00
1770.  324.2 130.4
1770.  324.2 130.4
1770.  324.2 130.4
.2
1.   1.   1.
/*
//
```

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